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Human factors and patient safety in undergraduate healthcare education: a systematic review.

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Review

Human factors and patient safety in undergraduate healthcare education: A systematic review

Patricia Sheehan[a,*], Aislinn Joy[c], Aoife Fleming[a], Helen Vosper[b], Suzanne McCarthy[a]

[a] School of Pharmacy, University College Cork, Cork, Ireland
[b] University of Aberdeen, Aberdeen, Scotland
[c] Medical Education Unit, School of Medicine, University College Cork, Cork, Ireland

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ABSTRACT

Background: WHO Global Patient Safety Action Plan 2021–2030 presents Human Factors (HF) capacity development as a core strategic objective. HF has been identified as a suitable framework for delivery of patient safety education. Findings of a previous review identified a lack of formally articulated patient safety curricula with Human Factors and Ergonomics largely absent.

Objective: to capture the extent to which HF is currently reported in the context of undergraduate healthcare curricula, and to characterise how it is reported using SEIPS 101.

Methods: Using a publication timeframe from 2016–2021 A systematic search was conducted using the following databases: Embase, Pubmed, Scopus, CINAHL and Eric. Relevant websites were searched for grey literature. The PETT (People, Environments, Tools and Tasks) component of SEIPS 101 was chosen as framework for data extraction and analysis.

Results: 25 papers were included in the review. In comparison with a previous review, findings demonstrate increased reporting of HF in the context of undergraduate healthcare curricula. SEIPS 101 helped identify both barriers and opportunities relating to HF implementation under the headings of people, environment, tools and tasks. Barriers included lack of shared safety language, lack of faculty expertise in patient safety (PS) as well as the lack of appropriate HF based competency framework to guide curriculum development. Opportunities included increased organisational collaboration between academic and clinical settings with respect to PS teaching. Educational accreditation bodies, and the professional regulators who influence them, were identified as important drivers of curricular change.

1. Introduction

Healthcare is a high-risk industry. The World Health Organisation (WHO) has described patient harm due to unsafe care as 'a large and growing global public health challenge' and 'one of the leading causes of death and disability worldwide' (WHO, 2021). There is an increasing move towards 'systems thinking' which comes with the realisation that healthcare is similar to other safety critical industries with respect to risk (WHO, 2021). When accidents happen, typically there is not one single root cause. Adverse events are not usually due to the actions of a single individual. A complex array of system factors, including work processes, team relationships, communication, human behaviour, technology, organizational culture, as well as environmental factors (CIEHF, 2018), can all impact the risk of an adverse event occurring (WHO, 2021). The WHO Global Patient Safety Action Plan 2021–2030[1] presents Human Factors (HF) capacity development as a core strategic objective in the context of 'building high reliability health systems'. Strategic Objective 2 of this plan identifies HF or ergonomics as 'key to the creation of high-reliability, resilient healthcare systems and organisations' (WHO, 2021).

The International Ergonomics Association has described HF as 'concerned with the understanding of interactions among humans and other elements of a system. It's the profession that applies theory, principles, data and methods to design to optimise human wellbeing and overall system performance' (CIEHF, 2018). Over the last 50 years, HF methods have been integrated across several high-risk industries such as aviation, oil and gas, the nuclear sector, defence and rail transport (Catchpole et al., 2021). It has been described as a 'bridging discipline' which establishes common ground between behavioural and physical elements involved in the relationship between humans and their working environments (Waterson & Catchpole, 2016). A core concept of HF is joint optimization of systems performance and the wellbeing of people (Vosper et al., 2018).

The adoption of HF principles for the management of risk within healthcare has been slow (Waterson & Catchpole, 2016). Healthcare sys-

* Corresponding author.
E-mail address: patricia.b.sheehan@gmail.com (P. Sheehan).

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tems are highly complex and dynamic which presents several unique challenges when compared with other safety critical industries. The scope of healthcare is not easily defined by set boundaries. The care environment can include a wide variety of settings including acute hospital, primary care as well as the home. People involved in patient care may include an array of healthcare professionals, as well as the patient themselves and their family (Holden & Carayon, 2021).

In other safety critical industries, HF focus therefore tends towards integrating humans, into work systems which have been specifically designed with known inputs, goals and constraints' (Catchpole et al., 2021). Healthcare is different, with systems and associated governance structures often developing organically over long periods of time. Resulting variability is described by Ornato & Peberdy (2014) who draw the following comparison between commercial aviation and healthcare: 'Commercial aviation crews operate with remarkable consistency and safety, while resuscitation team performance and outcomes are highly variable' (Ornato & Peberdy, 2014).

There is considerable and often necessary variation in work processes between healthcare organisations (Catchpole et al., 2021). The variable size, scope and membership of healthcare systems can make them difficult to understand (Institute of Medicine Committee on Quality of Health Care, 2000). Activity theorists have described how fragmentation of healthcare systems represents a particular challenge for patient care (Engeström & Pyörälä, 2021). There is a widespread lack of understanding within healthcare of what HF means and how it can be used to address complexity and improve patient safety within healthcare (Catchpole et al., 2021). When application of HF is cited, the focus is frequently on Non-technical skills (NTS) or Crew Resource Management (CRM) training, both of which focus heavily on communication skills, teamwork and situation awareness without consideration of the wider systems in which these will be applied (Catchpole et al., 2021).

Education of healthcare professionals represents a key strategy for improving safety within healthcare systems. Published literature on the topic suggests the need to expand formal patient safety teaching in healthcare curricula (Vosper & Hignett, 2018). For some time now, HF has been identified as a suitable framework for delivery of patient safety education (Vosper & Hignett, 2018; Vosper et al., 2018; WHO, 2011). The Chartered Institute of Ergonomics and Human Factors (CIEHF)(UK) has published a white paper which emphasises the need for inclusion of sufficient and relevant Human Factors education in clinical curricula (CIEHF, 2018). This interest in embedding HF within healthcare curricula is not new. The 2011 WHO Multi-professional Curriculum Guide (WHO, 2011) also emphasised it's role. An objective of the current WHO Global Patient Safety Action Plan (2021–2030) is the development of patient safety education in undergraduate as well as post-graduate healthcare curricula (WHO, 2021).

Gaps have been identified in relation to patient safety teaching in healthcare education. Vosper & Hignett (2018) published a review exploring the topic of patient safety and HF in both undergraduate and postgraduate healthcare curricula. This publication spanned the timeframe between 2007 and 2016. Findings identified a lack of formally articulated patient safety curricula with Human Factors and Ergonomics largely absent. Findings also identified a lack of primary research on the topic (Vosper & Hignett, 2018). Malcom et al. (2020) also highlight a gap in relation to HF content in undergraduate healthcare education. In their narrative review they outline that 'While the conceptual link between healthcare and aviation safety principles has been extensively explored, the extension of that link into pre-licensure training of health professions students has not been as well-studied (Malcom et al., 2020)'.

With increasing expectations that Human Factors content will be incorporated into patient safety education in undergraduate healthcare curricula, we require consolidated knowledge about how system factors affect healthcare processes and outcomes. Previous research indicates that much PS teaching of undergraduates takes place through the informal or hidden curriculum (while students are on clinical placement) (Vosper et al., 2018). The aim of this current review is to identify to what extent HF is currently reported in the context of undergraduate healthcare curricula, and to characterise how it is reported using a HF systems model (SEIPS 101) (Holden & Carayon, 2021). This review focuses on primary research published from 2016–2021 and seeks to explore any advancement in the integration of HF in undergraduate curricula since the previous review (Vosper & Hignett, 2018).

2. Methods

Search strategy: A systematic search was conducted using the following databases: Embase, Pubmed, Scopus, CINAHL and Eric. Official websites including the WHO and the Chartered Institute of Ergonomics and Human factors (UK) were also searched for relevant grey literature. Due to the interdisciplinary nature of the topic, the aim was to include educational and psychology databases as well as those with a healthcare focus. The following search terms were applied in Boolean combination [AND]: Human Factors or ergonomics or incident reporting or incident investigation; patient safety; student or undergraduate or curriculum or teaching or education. A previously published systematic review investigating Patient Safety and Human Factors teaching in healthcare curricula had searched for papers published between 2006 and 2017[10]. A publication timeframe of 2016 to the current date was therefore applied to the current search. The overlap of search timeframes was to help ensure that no articles were missed. All titles/abstracts were reviewed independently by at least two authors.

Eligibility criteria: Titles, abstracts and keywords were screened with the following inclusion criteria applied: Primary research publications referencing patient safety *and* HF education in undergraduate healthcare curricula; The terms 'Human Factors' or 'Ergonomics' appearing in title or abstract or keywords with publication in the English language. Papers relating solely to postgraduate education, surgery, anaesthesia, obstetrics, dentistry or medical devices were excluded. Hand searching of citations and references of included papers was conducted. There was no restriction on inclusion based on study design.

Quality appraisal: completed using Critical Appraisal Skills Programme (CASP) (CASP, 2018) or Joanna Briggs Institute (JBI) (JBI, 2017) critical appraisal checklists as appropriate to study design. Papers which contained the term 'Human Factors' in the title or keywords or which utilised a main intervention which was based on HF were categorised as having an emphasis on Human Factors.

Data extraction and synthesis: A primary descriptive extraction from included studies was tabulated using Microsoft Excel®. The following categories were included: student group, involvement of interprofessional education (IPE), study location (country), study objective(s), whether an educational intervention was used, study methods and results/conclusions. Studies were also categorised according to whether there was a focus on HF.

A secondary theoretical extraction was conducted using an HF framework (SEIPS 101) (Holden & Carayon, 2021). This framework facilitates consideration of a breath of elements in the studies (or work systems) reviewed. Various versions have been used by researchers and practitioners to understand or design sociotechnical systems. The PETT (People, Environments, Tools and Tasks) component of SEIPS 101[6] was chosen as the framework for data extraction and analysis for this review. The PETT Scan is presented by its creators as a flexible SEIPS 101 tool, with several potential applications. Examples of proposed applications include data collection, analysis and reporting (Holden & Carayon, 2021). In their paper entitled 'SEIPS 101 and seven simple SEIPS tool', authors Holden & Carayon (2021) illustrate how this tool may be utilised to classify work system factors as barriers and facilitators under the headings of 'people', 'environment', 'tools' and 'tasks'.

In the current review, the PETT Scan framework was applied as a classification system for theoretical analysis of extracted data. A deductive approach was used for data coding and analysis (Braun & Clarke, 2006). Qualitative data from selected studies was coded to PETT

headings of 'people', 'environment', 'tools' and 'tasks' for each paper prior to tabulation on Microsoft Excel®.

Data were extracted and recorded by a single researcher, and reviewed by the research team. The data were analysed for presence of interconnecting system components as well as barriers or facilitators to patient safety and HF education. PRISMA was used as a guide to reporting of the review (Moher et al., 2009).

3. Results

General study characteristics are summarised in Table 1 .

SEIPS data extraction table presented in Appendix 1.

A total of 25 papers met inclusion criteria for this review. 1493 records were initially identified from database searching with 498 duplicates removed prior to title and abstract screening. Following screening, 43 full text papers were retrieved and assessed against eligibility criteria. Citation and reference searching of included papers yielded 7 further publications which were retrieved for full-text review. 25 studies were selected for inclusion in the review. The search strategy is outlined in PRISMA flowchart (Fig. 1).

3.1. Study designs

The 25 selected studies demonstrated a diverse approach to study design. Some of the studies employed a cross-sectional descriptive study design which used a quantitative approach (Alquwez et al., 2019; Huang et al., 2020; Mbuthia & Moleki, 2019; Raymond et al., 2017; Usher et al., 2017). Others utilised either qualitative or mixed-methods design.

- **Professional disciplines** Eighteen studies were uni-professional and six studies involved Interprofessional Education (IPE).
  - Uniprofessional studies: Of the uni-professional studies, seven involved medicine, ten involved nursing and one focused on pharmacy.
  - IPE: Of the interprofessional groups, all included medical students (Caro-Rojas, 2018; Gordon et al., 2017; Ibrahim et al., 2017; Partecke et al., 2016; Reid et al., 2018; Wai et al., 2020), four of these included nursing students (Gordon et al., 2017; Partecke et al., 2016; Reid et al., 2018; Wai et al., 2020) and the remaining two included undergraduate pharmacy students (Caro-Rojas, 2018; Ibrahim et al., 2017). One large IPE based study also included students from audiology, cardiac physiology, midwifery, radiography, social work and an assistant practitioner programme (Reid et al., 2018).
  - One further study focused on surveying attitudes of the Resilient Healthcare Community in the context of syllabus development. (Sujan et al., 2019)
- **Educational interventions**

Fourteen of the studies involved an educational intervention (Allen et al., 2018; Backhouse & Malik, 2019; Beekman et al., 2019; Caro-Rojas, 2018; Gordon & Parakh, 2017; Gordon et al., 2017; Hanson et al., 2020; Ibrahim et al., 2017; Love & Zac-Varghese, 2020; McCoy et al., 2020; Partecke et al., 2016; Reid et al., 2018; Rudolphi, Madiraca, & Wheeler, 2019; Wai et al., 2020). All patient safety educational interventions were considered regardless of the degree of focus on HF. A diverse range of activities were presented. Examples ranged from 'escape room' participation (Backhouse & Ma-

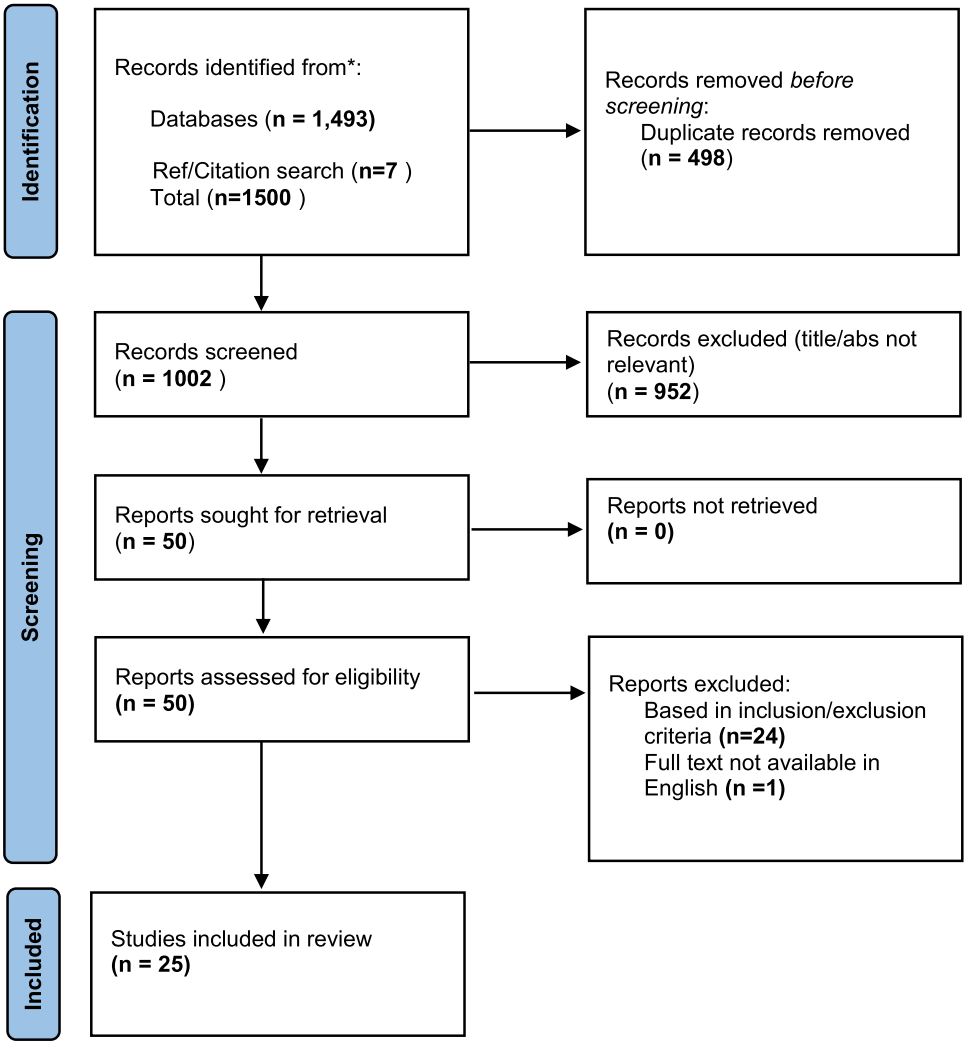

Fig. 1. Prisma (Moher et al., 2009) Flowchart detailing search

Table 1
Summary of Study Characteristics.

Study author/Country	Title	Objective:	Persons	HF Focus	Educational Intervention	Methods:	Results/Conclusions
Allen et al. (2018) UK	Human factors training for medical students: exploring student perception and how to promote a better understanding	To identify the attitudes of medical students towards human factors training and how a training programme can affect career preparedness	3rd and 5th year medical students (*n* = not specified)	Yes: HF training session (content not detailed)	Yes - Educational session aimed at highlighting areas of HF training; (faculty expertise not specified)	HF training session aimed at highlighting areas of human factors training and how this can be applied to the student's own Practice; Pre and post training student questionnaires.	Students' perception of human factors training is limited and the training session improved understanding
Alquwez et al. (2019) Saudi Arabia	A multi-university assessment of patient safety competence during clinical training among baccalaureate nursing students: A cross-sectional study	Assessment of self-reported PS competencies of UG nursing students at 6 universities	3rd, 4th and 5th year nursing students (n=829)	no	no	Descriptive cross-sectional design. Health Professional Education in Patient Safety Survey (H-PEPSS) survey tool (culturally adapted Arabic version) Outcome measure: self reported confidence in PS	Saudi nursing students have positive perceptions towards their PS competencies. The percentage of agreement on the items of the health professional education in patient safety survey ranged from 61.5 to 76.5%. The dimension 'understanding human and environmental factors' received the highest perceived competence.
Backhouse and Malik (2019) UK	Escape into patient safety: bringing human factors to life for medical students	To create a learning environment which gave students an appreciation of how the skills being taught are used within a clinical setting to promote patient safety	3rd year medical students *n* = 19	Yes – classroom based introductory HF teaching (content not detailed); escape room with NTS focus;	Yes: escape room—a team-based game where students solve a series of clinical and communication-based tasks; Followed by 'after action review' and classroom based teaching.	Mixed methods design: educational interventions followed by student evaluation using a feedback form.	100% of students agreed or strongly agreed they gained new knowledge and skills and insights. 100% felt confident or very confident they would be able to apply what they had learnt in the future.
Bahadur et al. (2018) Pakistan	Patient safety as integrated part of medical curricula: Perceptions of postgraduate medical doctors from two selected teaching institutes Peshawar Pakistan	Exploration of postgraduate medical doctors' views on patient safety as integrated part of UG and PG medical curricula	Trainee medical officers	no	no	Qualitative study based on exploratory design. Data gathered through focus group discussions followed by thematic analysis. Outcome measure: PG medical doctors' views on PS as integrated part of medical curricula	Participants indicated that Patient Safety curriculum should be the part of undergraduate and post graduate medical curriculum c.75% of the participants perceived that patient safety related incidence also occurs due to fault in the system
Beekman et al. (2019) US	Patient Safety Morning Report: Innovation in Teaching Core Patient Safety Principles to Third-Year Medical Students	Implementation of patient safety curriculum for the student cohort	3rd year medical students (*n* = 63)	no	Yes: Two sessions, 90 min each conducted during students' Paediatric Clerkship; included brief didactic presentation; students presented PS case (based on SAFE Framework),	Mixed methods. Educational intervention followed by quantitative analysis using post-intervention likert-type questionnaire. Free text feedback section included.	The most common themes identified were Communication (57% of cases), Human factors (39%) and System issues (37%) 85% of students favoured additional PS and QI education.

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Table 1 (*continued*)

Bohomol (2019) Brazil	Patient safety education of the graduation in Nursing from the teaching perspective	Identification of contents related to Patient Safety contemplated in the curricular units of a Nursing undergraduate course	Professors responsible for undergraduate nursing course (n = 15)	no	no	Descriptive case study with a qualitative approach. 3 item online questionnaire based on WHO Patient Safety Curriculum Guide (Multi-professional editon). [11] Participants provided qualitative responses. For the analysis of data, reference was made to the WHO guide. Outcome measure: identification of contents related to PS in curricular units of a nursing course	It was verified that patient safety contents are developed in the undergraduate course, referring to eight topics mentioned in the World Health Organization guide. There was a lack of content on the topics "What is Patient Safety", "Why applying human factors is important for Patient Safety"; and "Learning from errors to prevent harm".
Caro-Rojas (2018) Colombia Conf. abs	Health care communication empowerment: A successful programme in Colombia	To describe the experience with pharmacy and medicine students using role-play and theatre practices	IPE (pharmacy and medical students; n = 400)	no	Yes – 'Health Care Communication empowerment defined as: use of non-conventional tools for the development of communication skills, which the empowerment of the actors in the provision of health services; role play involved	Methods not detailed	Positive feedback from students
Gordon and Parakh (2017) UK	Medical students' perceptions of a novel institutional incident reporting system: A thematic analysis	To describe the incident reporting system and assess how students perceived the system with regards to its role in enhancing safety	1st year medical students (n = 27)	Yes – incident reporting presented in a HF context; strong NTS emphasis	Yes – students took part in school IR system	Qualitative methods using thematic analysis. Interviews with medical students at the end of the first year. Thematic indices were developed according to the information emerging from the data. Grounded theory approach. Outcome measure: assess how students perceived reporting system with regards to its role in enhancing safety	Students did not interpret reporting as a manner to support institutional learning and safety, rather many perceived it as a tool for a blame culture. Students did accept the safeguarding aspect of reporting.

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Table 1 (*continued*)

Gordon et al. (2017) UK	Learning health 'safety' within non-technical skills interprofessional simulation education: a qualitative study	Identification of how the context of interprofessional simulation learning influences NTS acquisition and development of 'safety' amongst learners	IPE (n = 13; junior doctors, undergraduate medical student, second-year undergraduate student nurses, third-year undergraduate student nurses, pharmacists, occupational therapist)	Yes: intervention focus is NTS (presented in HF context)	Yes - NTS training: three-session simulation-based intervention took place in simulation suite (designed using SECTORS model);	Qualitative design. Intervention followed by focus group interview (part of TINSELS programme) -; Focus on 'NTS acquisition within the context of interprofessional simulation training' Analysis was aligned with a constructivist paradigm and took an interactive methodological approach	Interprofessional learner groups undertaking simulation-based training can support the development of NTS that can dissipate intergroup contact anxiety
Hanson et al. (2020) Australia	Speaking up for safety': A graded assertiveness intervention for first year nursing students in preparation for clinical placement: Thematic analysis	To elicit student and staff perspectives on quality, effectiveness and appropriateness of training programme	1st year nursing students (n = 73)	no	Yes: Communication module offered in the second week of a practice laboratory and involved the use of two graded assertiveness frameworks (PACE and CUSS)	Qualitative design with thematic analysis; educational intervention followed by 7-item qualitative survey and semi-structured individual interviews	Establishing a preparatory framework for 'speaking up for safety' in first year undergraduate nursing curricula had important psychosocial implications for student confidence, empowerment and success
Huang et al. (2020) China	Self-reported confidence in patient safety competencies among Chinese nursing students: A multi-site cross-sectional survey	Measurement of self-reported patient safety competence of students using the H-PEPSS tool	Final year nursing students (n = 732 - recruited across 7 universities)	no	No	Multi-site cross sectional survey using H-PEPSS tool Outcome measure: self reported confidence in PS	Chinese undergraduate nursing students were fairly confident in their clinical safety skills but less confident in what they learned about sociocultural aspects. 44.8% felt they could approach someone engaging in unsafe practice" and 46.9% perceived "consistency in how PS issues are dealt with by different instructors"
Ibrahim et al. (2017) US	Analysis of the effect of an interprofessional educational program on medical students' knowledge and attitudes regarding patient safety and interprofessional learning	Analysis of effect of programme on medical student PS attitudes, knowledge and impact of IP learning.	IPE: (medical and pharmacy students)	no	Yes: 4 h program included mini-lectures, Grey's Anatomy episode portraying a medical error, and IP group work	Mixed methods design.; Students completed investigator created pre-survey assessing PS knowledge and attitudes and the Healthcare Professionals Patient Safety Assessment Curriculum Survey (HPPSACS) added at midpoint of year. Post surveys contained added program evaluation items. Outcome measure: self assessed student PS knowledge and attitudes	Self-assessment of PS knowledge increased Post-program more students believed working in an IP team improved PS (92 to 99%, $p < 0.05$). More students strongly agreed errors should be evaluated by IP committees (35 to 61%, $p = 0.003$)

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Table 1 (*continued*)

Jang & Lee (2017) South Korea	Patient safety competency and educational needs of nursing educators in South Korea	Assessment of nursing educators' competencies and educational needs for patient safety in hospitals and nursing schools	School clinical instructors (38) and hospital nurse preceptors (106)	no	no	Mixed-methods sequential explanatory design employed a survey and focus group interview with nursing educators (school clinical instructors and hospital nurse preceptors).Surveys were analysed to obtain quantitative data. Focus group interviews were used to obtain qualitative data. Outcome measure: nursing educators' competencies and educational needs	Nursing educators had higher levels of attitude compared with relatively lower levels of skill and knowledge regarding patient safety
Love & Zac-Varghese (2020) UK	Novel simulation-based human factors workshops for nearly qualified doctors	To improve medical student confidence and awareness of HF in the weeks immediately prior to commencing their first employment as junior doctors	Final year medical students (n = 44)	Yes: brief introductory lecture introducing HF concepts (content not detailed); Focus is on 'promoting awareness of NTS'	Yes: half-day interactive workshop combining didactic teaching with four simulation-based activities; individually followed by collective debriefing and discussion	Mixed methods; mixed educational intervention; HuFSHi tool (quantitative) utilised pre and post intervention Outcome measure: self-reported confidence of students (HuFSHI parameters)	The mean total HuFSHI confidence score prior to starting the workshop was 5.89 (95% CI 5.44 to 6.33). Immediately after the workshop and debriefing sessions, the mean total confidence score was 6.62 (95% CI 6.22 to 7.02) with the paired sample t-test p value ≤0.001. The intervention effective and well received by medical students
Mbuthia and Moleki (2019) Kenya	Preregistration nursing students' perceived confidence in learning about patient safety in selected Kenyan universities	Measurement of self-reported patient safety competence of students	2nd, 3rd and 4th year nursing students (n = 194 - two universities)	no	no	Cross-sectional descriptive study using a quantitative approach. H-PEPSS tool was distributed to the participants during their break times from class Outcome measure: self reported confidence in PS	Students reported higher confidence about learning on the clinical aspects than on the sociocultural issues of patient safety with the lowest mean scores recorded in 'Understanding human and environmental factors' and 'Recognising, responding and disclosing adverse events'. 52.2% felt that reporting a patient safety problem will result in negative repercussions
McCoy et al (2020) US	Learning to Speak Up for Patient Safety: Interprofessional Scenarios for Training Future Healthcare Professionals	Design of an electronic suite of cases for medical students to learn how to speak up for patient safety in a medical setting and to evaluate student understanding of specific methods for voicing concerns	Second-year medical students (n = 97)	no	Yes: Students completed 4 digital case studies on PS (include NTS focus) and 11 assessment questions with instant feedback; participated in short case debrief discussions and provided some qualitative answers.	Mixed methods design. Mixed educational intervention followed by 12 question post-test to assess learning. Outcome measure: evaluation of student understanding of specific methods for voicing concern	Post-test had mean score of 96.5%. Student written responses to the 4 case discussion prompts indicated a high level of comprehension. This training method was cost-effective and could be replicated in other online learning or blended learning environments

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Table 1 (*continued*)

Partecke et al. (2016) Germany	Interprofessional learning - Development and implementation of joint medical emergency team trainings for medical and nursing students at Universitätsmedizin Greifswald	Development, implementation and evaluation of a simulation based interprofessional course module on clinical emergency medicine	IPE: medical students (n = 120) and nursing students (n = 120)	Yes: introduced as 'a project to increase patient safety by integrating interprofessional human factor training into the curriculum of both health professions'; (CRM approach used)	Yes: Introduction to theory followed by application of knowledge in simulated case scenarios; The assignment was to examine a simulated patient in a hospital setting as an interprofessional team, to make a working diagnosis, and to undertake necessary actions as a team	Mixed methods design. Mixed educational intervention involving simulation and CRM; Debriefing sessions took place following each case scenario; Subjective experiences discussed and analysed;Student satisfaction with module documented using standardized questionnaire (likert-like scale)	On a scale from 1 to 5 (1 = excellent, 5 = inadequate), initial mean ratings were 1.34 for medical students (n = 96; SD = 0.52), and 1.37 for nursing students (n = 102; SD = 0.49) representing a high student satisfaction rating
Raymond et al. (2017) Canada	Baccalaureate nursing students' confidence on patient safety	Measurement of self-reported patient safety competence of students	Nursing students from all four years (n = 458; across two universities)	no	no	Quantitative descriptive cross-sectional method with H-PEPSS tool (adapted version) used to assess self reported PS competency Outcome measure: self reported confidence in PS	Students report most confidence in hand hygiene, infection control and medication safety practices. Students reported least confidence relating to working in teams, human and environmental factors, adverse events and culture of safety. Between 51% and 61% of students expressed that there is consistency demonstrated by preceptors in dealing with patient safety issues
Reid et al. (2018) UK	Learning from interprofessional education: A cautionary tale	Quantitative and qualitative evaluation of IPE Pilot	IPE:first year students from audiology, cardiac physiology, nursing, medicine, midwifery, radiography, social work and the assistant practitioner programme (n=630)	Yes: a half day case-based IPE seminar on patient safety (human factors theory – content not detailed); focus on NTS	Yes: included Powerpoint presentation on human factors theory; activities which provided opportunity for students to discuss their programme and placement experiences; a case-based discussion exploring a failure in teamwork; took place on campus	Mixed methods design. Students completed a paper-based survey at the end of a large scale IPE pilot to rate the session using a four-point Likert scale; students were invited to take part in uni-professional focus groups to explore themes arising from the survey Outcome measures: student rating of session (quantitative data) Illicit student views (qualitative data)	Three overarching themes emerged from analysis of the qualitative data: Understanding differences in roles, Learning about stereotypes and unintended perpetuation of stereotypes. The majority of respondents agreed the session was useful in adding value (75.5%), in appreciating other professional roles (80.6%), and understanding teamwork in patient safety (84.7%). Only a minority agreed it had been useful in enhancing the learning from the associated module specific to their programme (28.1%)
Rudolphi et al. (2019) US	Medical-Surgical Clinical Student Error and Near-Miss Event Reporting	Identification of medical-surgical clinical error near-miss events (ENME) and causative factors as reported	Senior level nursing students	no	Yes: Students were asked to complete error report using an adapted Qualtrics® survey (based on Eindhoven model of incident classification) for any clinical ENME. Students were given instruction during a one-hour clinical orientation and a follow-up explanation in a one-hour didactic seminar course.	Mixed methods design; Qualitative and quantitative data obtained Outcome measure: identification of medical-surgical clinical ENME and causative factors as reported by senior-level nursing students	Students identified cognitive and behavioural/performance issues, human factors, system issues, and communication as contributing factors, with 97% of errors reported as preventable. Identifying ENMEs with causative factors may ultimately increase patient safety.

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Table 1 (*continued*)

Sujan et al. (2019) International	Towards a syllabus for resilient health care	To consult the wider resilient healthcare (RHC) community of researchers and practitioners to identify topics, concepts and mindsets and teaching approaches that could form the basis for a resilient health care syllabus	Contributors to books on RHC, members of resilient health care network, and personal contacts of authors	Yes: topic is Resilience Engineering (aligns with HF principles);	no	Online 7-item qualitative survey completed by participants Explored views from the wider RHC community of researchers and practitioners about topics, concepts and mindsets, and teaching approaches that could form the basis for a resilient health care syllabus Constructivist pedagogical principles emphasising peer learning and sharing of principles favoured	Identified lists of candidate ideas about theoretical concepts, practical tools and methods, changes in attitudes and teaching approaches relevant to Resilient Healthcare Identified some controversial topics, such as the extent to which traditional approaches are compatible with RHC principles Consensus that teaching RHC should be aimed at supporting and enhancing ability to work and learn in multidisciplinary groups
Usher et al. (2017) Australia	Self-reported confidence in patient safety knowledge among Australian undergraduate nursing students: A multi-site cross-sectional survey study	Measurement of self-reported patient safety competence of students	1st, 2nd and 3rd year nursing students (n = 1319; across 7 universities)	no	no	Multi-site, cross-sectional study using quantitative approach. Participants surveyed using H-PEPSS tool Building on Bandura's (1988) theory of self-efficacy Outcome measure: self reported confidence in PS	Participants were most confident in their learning of clinical safety skills and least confident in learning about the sociocultural dimensions of working in teams with other health professionals, managing safety risks and understanding human and environmental factors. Only 59% of students felt confident they could approach someone engaging in unsafe practice, 75% of students agreed it was difficult to question the decisions or actions of those with more authority, and 78% were concerned they would face disciplinary action if they made a serious error.
Vosper & Hignett (2018) UK	Factors influencing the development of effective error management competencies in undergraduate UK pharmacy students	To complete a pilot case-study to explore PS teaching in a purposively-selected sample of UK pharmacy schools	Staff and students at two UK Pharmacy Schools	Yes: objectives include: -audit of course documentation for PS and HF content; -exploration of staff and student perceptions of PS and HF teaching	no	Qualitative study design. Audit course documentation for PS and HF framed as explicit outcomes; use interviews/focus groups to explore staff and student perceptions of PS/HF teaching; identify good practice and areas for development and framing recommendations Constructivist grounded theory used to underpin analysis	Curriculum mapping found very little systems content; Results revealed barriers to PS teaching including risk-averse pharmacist 'personality' and Educational Standards negatively influencing students' error-management behaviours

(*continued on next page*)

Table 1 (*continued*)

Wai et al. (2020) China	Exploring the role of simulation to foster interprofessional teamwork among medical and nursing students: A mixed-method pilot investigation in Hong Kong	Comparison of the effectiveness of blended classroom plus clinical simulation versus clinical simulation alone on teamwork attitudes, perceptions and performance	IPE:Undergraduate students in medicine (year 5; $n = 19$) and nursing (years 3 and 4; $n = 27$) programmes in Hong Kong	No – main focus is simulation training and CRM (however modified Human Factors Attitudes Survey used as one of the assessment tools)	Yes: interprofessional CRM training programme; Students were allocated to either blended classroom plus simulation or simulation alone; Focus groups as well as a mixture of pre and post tests were utilised to assess learning	A mixed-method approach with an observational, quasi experimental design and qualitative content analysis. Assessment tools included HFAS (modified version of Human Factors Attitudes Survey), the Team-Based Learning Student Assessment Instrument and Ottawa Global Rating Scale, The primary outcome was attitudinal change related to teamwork behaviours, measured using the Human Factors Attitude Survey. The secondary outcomes were perceptions of team-based learning and teamwork performance, which were accessed by the Team- Based Learning Student Assessment Instrument and Ottawa Global Rating Scale, respectively	Blended classroom did not further improve teamwork attitudes, perceptions and performance in medical and nursing students compared with clinical simulation only. There was a significant increase in the participants' positive attitudes on teamwork for both groups (intervention: Mean difference (*MD)* = 5.36 and control: *MD* = 3.6, $p < 0.05$); however, there was no significant difference on increasing positive attitudes between the groups (estimate = 1.76, 95% CI [−8.59, 5.06], $p = 0.61$)
White et al. (2016) UK	The Introduction of "Safety Science" into an Undergraduate Nursing Programme at a Large University in the United Kingdom	To describe how safety science education was embedded into a pre-registration nursing programme at a large UK university	Nursing	Yes: 'Safety Science' described as 'a term adopted by the authors which incorporates both patient safety and Human factors'	Safety Science education was embedded into a pre-registration nursing programme of a large UK university	Literature search, developing programme content, implementing programme change The UK Institute for Innovation and Improvement (2010) safety science competency framework was utilised to aid development of theoretical framework. Links were also made to the UK Nursing & Midwifery Council Pre-registration Standards (2010) domains	Safety Science education was embedded into a pre-registration nursing programme of a large UK university. Authors suggest process may be used as template for others in implementing safety science into pre-registration nursing and other healthcare programmes

HF = Human Factors PS = Patient Safety UG = Undergraduate RHC = Resilient Healthcare

lik, 2019) to didactic lectures (Beekman et al., 2019; Love & Zac-Varghese, 2020) and case studies (Bohomol, 2019; McCoy et al., 2020; Partecke et al., 2016). Several studies used a combination of interventions. Some studies combined classroom-based learning with practical activities such as simulation (Love & Zac-Varghese, 2020; Wai et al., 2020). Others combined watching video material with group work (Ibrahim et al., 2017) which included role play exercises (Caro-Rojas, 2018) or simulation (Love & Zac-Varghese, 2020). Examples of televised material included watching a 'Grey's Anatomy' episode portraying a medical error (Ibrahim et al., 2017) and a video entitled 'Just a routine operation' (by Martin Bromiley) (Beekman et al., 2019; Love & Zac-Varghese, 2020). Where task-based interventions were used, the focus was predominantly on 'non-technical skills' or CRM training (Backhouse & Malik, 2019; Gordon et al., 2017; Hanson et al., 2020; Love & Zac-Varghese, 2020; Partecke et al., 2016; Wai et al., 2020) .

Six studies which utilised educational interventions involved IPE (Caro-Rojas, 2018; Gordon et al., 2017; Ibrahim et al., 2017; Partecke et al., 2016; Reid et al., 2018; Wai et al., 2020). The IPE based interventions ranged from case based discussions, to mini-lectures followed by watching a 'Grey's Anatomy' episode portraying a medical error (Ibrahim et al., 2017), to simulation-based NTS (Gordon et al., 2017) or CRM (Partecke et al., 2016; Wai et al., 2020) training.

Student feedback: Students seemed to largely enjoy learning about patient safety through these educational based interventions. From the uni-professional studies, where student feedback on the educational interventions was obtained, it was mainly positive (Backhouse & Malik, 2019; Beekman et al., 2019; Caro-Rojas, 2018; Hanson et al., 2020; Love & Zac-Varghese, 2020; Partecke et al., 2016). Student feedback was obtained in a variety of ways including semi-structured interview (Hanson et al., 2020), post intervention questionnaires (Beekman et al., 2019; Partecke et al., 2016) and feedback forms (Backhouse & Malik, 2019). Semi-structured interviews described by Hanson et al. (2020) indicated that 'students felt empowered following the class and the frameworks gave them confidence in preparation for their first clinical placement' (Hanson et al., 2020). The study by Gordon and Parakh (2017) demonstrated a notable exception as students 'did not interpret a faculty based incident reporting system as a manner to support institutional learning and safety, rather many perceived it as a tool for a blame culture' (Gordon & Parakh, 2017).

- **Self-reported PS competence using the Health Professional Education in Patient Safety Survey (H-PEPSS)**

  Five papers focused solely on gathering self-reported PS competence and targeted undergraduate nursing students. These studies were conducted in Saudi Arabia (Alquwez et al., 2019). China (Huang et al., 2020), Kenya (Mbuthia & Moleki, 2019) Canada (Raymond et al., 2017) and Australia (Usher et al., 2017). All five utilised the H-PEPSS tool (including adapted versions) which is a validated instrument underpinned by WHO PS competency domains (WHO, 2011). 'Human and environmental factors' is one of the six competency domains measured by the H-PEPSS survey. It is designed to measure health professionals' self-reported PS competence around the time of entry to practice (Ginsburg et al., 2012). Chinese, Kenyan and Australian undergraduate nursing students all reported relatively high confidence in their clinical safety skills but less confidence in what they learned about sociocultural aspects of PS including human and environmental factors (Huang et al., 2020; Mbuthia & Moleki, 2019; Usher et al., 2017). Canadian nursing students also reported least confidence relating to working in teams, human and environmental factors, adverse events and culture of safety (Raymond et al., 2017).

- **Perspectives of educators**

  Four studies gathered faculty perspectives on teaching of PS in undergraduate curricula (Bahadur et al., 2018; Bohomol, 2019; Helen & Sue, 2017; Jang & Lee, 2017). Both qualitative (Bahadur et al., 2018; Bohomol, 2019; Helen & Sue, 2017) and mixed methods (Jang & Lee, 2017) approaches were taken which included staff interview (Helen & Sue, 2017) and focus groups (Bahadur et al., 2018; Helen & Sue, 2017; Jang & Lee, 2017) as well as surveys (Bohomol, 2019; Jang & Lee, 2017). Although results indicated a positive attitude to curricular implementation of PS (Bahadur et al., 2018), low levels of faculty expertise (Helen & Sue, 2017; Jang & Lee, 2017) including a lack of understanding of error (Helen & Sue, 2017) was highlighted. Investigation of curricular content identified a lack of Human Factors and PS content. (Bohomol, 2019; Helen & Sue, 2017)

3.2. HF focus

Of the twenty-five articles, ten studies were categorised as having an emphasis on Human Factors (three papers referred to Human Factors in the title (Allen et al., 2018; Backhouse & Malik, 2019; Love & Zac-Varghese, 2020) five included Human Factors in the keywords (Gordon & Parakh, 2017; Gordon et al., 2017; Helen & Sue, 2017; Sujan et al., 2019; White et al., 2016), a further two included 'human factors' training as main interventions (Partecke et al., 2016; Reid et al., 2018)). Of the papers considered to have less emphasis on HF, five reported HF only in the context of the Health Professional Education in Patient Safety Survey (H-PEPSS) (Ginsburg et al., 2012) .. A further six studies had a Patient Safety focus with HF included in the narrative but not as a central theme (Bahadur et al., 2018; Beekman et al., 2019; Jang & Lee, 2017; McCoy et al., 2020; Rudolphi et al., 2019; Wai et al., 2020) Four studies mentioned the term 'Human Factors' but contained little further detail on the topic (Bohomol, 2019; Caro-Rojas, 2018; Hanson et al., 2020; Ibrahim et al., 2017).

- **HF-based interventions:** Seven studies specified use of HF-based educational interventions (Allen et al., 2018; Backhouse & Malik, 2019; Gordon & Parakh, 2017; Gordon et al., 2017; Love & Zac-Varghese, 2020; Partecke et al., 2016; Reid et al., 2018). Of these, six used interventions which were based on either NTS (Backhouse & Malik, 2019; Gordon & Parakh, 2017; Gordon et al., 2017; Love & Zac-Varghese, 2020; Reid et al., 2018) or CRM training (Partecke et al., 2016) two of which also involved IPE (Gordon et al., 2017; Partecke et al., 2016). Activities included simulation (Gordon et al., 2017; Love & Zac-Varghese, 2020; Partecke et al., 2016), case based discussion (Reid et al., 2018), participation in a school incident reporting system (Gordon & Parakh, 2017) and taking part in a competitive escape room (Backhouse & Malik, 2019). Where delivery of didactic HF theory was included, the specific content was not detailed (Backhouse & Malik, 2019; Love & Zac-Varghese, 2020; Reid et al., 2018). Allen et al. (2018) report delivery of Human Factors training to 3rd and 5th year medical students however detail on the substance of this training was not provided (Allen et al., 2018).

  Assessment of HF-based interventions: assessment of HF-based educational interventions was not underpinned by a HF competency framework encompassing the full scope of HF. Two studies involved surveys which had a named focus on HF. Wai et al. (2020) used a modified Human Factors Attitude survey as one of a selection of instruments, while Love & Zac-Varghese (2020) used the Human Factors Skills for Healthcare Instrument (HuFSHI). Both these tools focus solely on measurement of NTS.

- **Resilient healthcare (RHC)**

  A study by Sujan et al. (2019a) focused on surveying attitudes of the Resilient Healthcare Community in the context of RHC syllabus development . Learning from 'work as done' is key to the

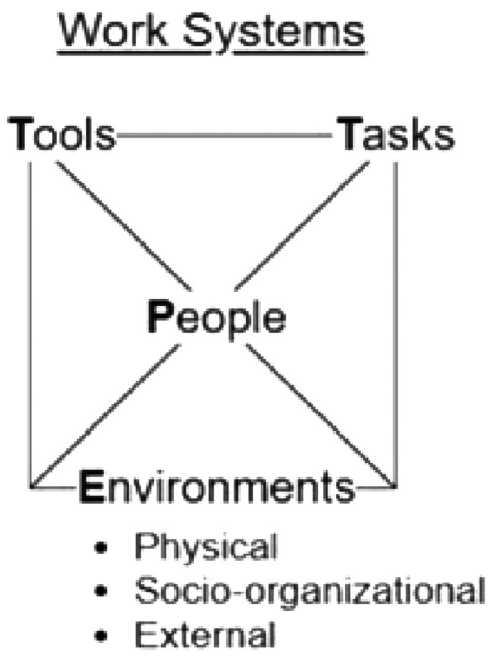

Fig. 2. PETT Scan (SEIPS 101) (Holden & Carayon, 2021).

RHC approach as described by the authors. The resilient healthcare community were consulted to identify topics, concepts and mindsets and teaching approaches that could form the basis for a resilient health care syllabus. The extent to which traditional approaches such as those that focus on adverse event scenarios, are compatible with RHC principles (Sujan et al., 2019b) was a key topic which emerged.

3.3. Theoretical data extraction using SEIPS 101[6]

Using SEIPS 101[6], data were mapped to PETT headings of Persons', 'Environmental factors (including Organisational Factors), 'Tools and Technology', and 'Tasks'; Barriers and opportunities are identified under these PETT Scan headings.

A summary of SEIPS findings is presented below**.** SEIPS 101 data extraction is included in full in Appendix 1. Fig. 2 Illustrates how components may be viewed as interconnecting work system elements using the SEIPS 101 PETT Scan (Holden & Carayon, 2021).

SEIPS 101 Summary of Findings:

Persons:

- There is a demonstrated a lack of shared language concerning Human Factors: e.g. using the term 'Human factors' to describe factors such as 'stress', 'fatigue' and 'emotion'. (McCoy et al., 2020) Some studies classified 'human factors' separately to 'system factors' (Jang & Lee, 2017) or 'teamwork'. (Alquwez et al., 2019; Huang et al., 2020; Mbuthia & Moleki, 2019; Raymond et al., 2017; Usher et al., 2017)
- A lack of faculty and clinical preceptor expertise was repeatedly presented as a barrier to teaching Patient Safety (Backhouse & Malik, 2019; Bohomol, 2019; Helen & Sue, 2017; Jang & Lee, 2017; Reid et al., 2018; White et al., 2016);
- Majority of studies are uni-professional – representing a gap in context IPE
- Very few studies involve pharmacy

Tools and technologies:

- WHO Patient Safety Curriculum guide (2011) frequently underpinned research, however there are challenges regarding its presentation of HF (Sujan et al., 2019; Vosper & Hignett, 2018)
- Where interventions included teaching of 'Human Factors' there was a lack of HF competency-based assessment tools to measure learning

Tasks:

- Where task-based interventions were used, the focus was predominantly on 'non-technical skills' or CRM training

Environment:

- There is a reliance on the clinical environment for teaching patient safety (Huang et al., 2020; Jang & Lee, 2017; Usher et al., 2017)
- Resource constraints within the healthcare environment were reported as having a negative impact on Patient Safety learning (Bohomol, 2019; Jang & Lee, 2017; Mbuthia & Moleki, 2019)
- The negative impact of a hierarchical healthcare environment was highlighted by some authors as a PS challenge (Hanson et al., 2020; Huang et al., 2020; Reid et al., 2018)
- Several studies emphasised the need for organisational collaboration between academic and clinical settings with respect to PS teaching (Hanson et al., 2020; Huang et al., 2020; Jang & Lee, 2017; Love & Zac-Varghese, 2020; Mbuthia & Moleki, 2019; Rudolphi et al., 2019; Usher et al., 2017)

Global research environment:

- although there is an increasing emphasis on the topic of Human Factors in undergraduate healthcare curricula, there remains an overall lack of primary research in the area

Organisational impacts on the educational environment:

- The importance of organisational support with respect to developing Patient Safety curricula was a recurring theme (Bahadur et al., 2018; Helen & Sue, 2017; Jang & Lee, 2017; White et al., 2016)
- Educational accreditation bodies (Alquwez et al., 2019; Beekman et al., 2019; McCoy et al., 2020), and the professional regulators who influence them (Helen & Sue, 2017), are perceived as important drivers of curricular change
- National legislative frameworks can influence environmental safety culture (Helen & Sue, 2017)

The WHO Multiprofessional Curriculum Guide (2011) was cited across several of the selected publications. (Bahadur et al., 2018; Bohomol, 2019; Jang & Lee, 2017; Mbuthia & Moleki, 2019; Usher et al., 2017; Wai et al., 2020; White et al., 2016)

4. Discussion

The primary objective of this research was to establish the extent to which HF is currently reported in the context of undergraduate healthcare curricula. A further objective was to characterise *how* HF is reported.

Findings demonstrate that the topic of human factors education in undergraduate healthcare curricula is gaining purchase. In their review which was published in 2018, Vosper and Hignett describe how 'very few studies reviewed involved HF' (Vosper & Hignett, 2018). In contrast, the current review which focuses only on undergraduate healthcare curricula identified 25 primary research studies which met inclusion criteria. Ten of these papers were classified as presenting Human Factors as a central topic. Despite this increase, the overall body of research on the topic remains low.

This increased reference to HF in the literature aligns with evidence of an evolving international profile. Groups such as the Human Factors and Ergonomics Society (HFES), the Chartered Institute of Human Factors and Ergonomics (CIEHF) and the Clinical Human Factors Group (CHFG) are working to raise the profile of HF' (Waterson & Catchpole, 2016). At international level, the WHO Global Patient Safety Action Plan 2021–2030 now presents Human Factors (HF) capacity development as a core strategic objective in the context of 'building high

reliability health systems' (WHO, 2021). From an Irish perspective, the Health Service Executive (HSE) produced the Patient Safety Strategy (2019–2024) which includes building Human Factors capacity in healthcare services and staff as a strategic aim (HSE, 2021).

A further objective of this review was to characterise *how* HF is reported in the context of undergraduate healthcare education. The SEIPS 101 'PETT scan' tool was chosen to help characterise reporting with particular emphasis on the people involved, the environment, tools and tasks (Holden & Carayon, 2021). A key advantage of using SEIPS is the interconnectivity apparent between the various system entities when classified according to this framework:

4.1. People and language

Most of the selected papers involved either medical or nursing students. Pharmacy was under-represented with just three of the twenty five studies involving pharmacy curricula. This finding is in agreement with the previous review which also demonstrated a lack of literature concerning teaching of PS to pharmacy students (Vosper & Hignett, 2018). Just six of the selected papers involved IPE. This represents a gap in the literature as IPE has been identified as an ideal forum for patient safety education (Vosper et al., 2018; WHO, 2021). The WHO Global Patient Safety Action Plan (2021–2030) has emphasised that 'interprofessional and multidisciplinary approaches, are needed if education and training are to play the full role that they should in improving patient safety' (WHO, 2021). Pharmacists have a valuable contribution to make as part of the multidisciplinary team (Hurley et al., 2021; Vosper & Hignett, 2018). Inclusion of pharmacy students in future IPE initiatives will strengthen the multidisciplinary approach to patient safety.

A lack of faculty expertise was repeatedly presented as a barrier to teaching Patient Safety (Backhouse & Malik, 2019; Bohomol, 2019; Helen & Sue, 2017; Jang & Lee, 2017; Reid et al., 2018; White et al., 2016). This finding concurs with findings from Vosper and Hignett (2018) who also observed how 'academic staff members have very little understanding of the factors that influence student learning about safety' (Vosper & Hignett, 2018). Several papers in this review highlighted a lack of consistency in clinical preceptor approaches to Patient Safety (Huang et al., 2020; Mbuthia & Moleki, 2019; Raymond et al., 2017; Usher et al., 2017). This current lack of expertise represents a barrier to HF implementation in healthcare. In the absence of undergraduate training, the baseline knowledge of PS and HF among healthcare professionals will remain low. Previous research indicates that valuable transfer of knowledge is associated with implicit education delivered by non-academic staff during clinical placement. (Vosper & Hignett, 2018) Harnessing the potential of the hidden curriculum represents an opportunity for patient safety teaching. Today's students are tomorrow's healthcare professionals. Given the strong influence the informal and hidden curricula on student learning (Vosper & Hignett, 2018), the current knowledge base represents a perpetuating problem for patient safety.

When HF was discussed, there was a demonstrated lack of shared terminology or language between publications. There was much variation in authors' interpretation of the term 'Human Factors'. Few authors used the term in a way which aligned with accepted definitions including those of the CIEHF(UK). Examples include using the term 'Human factors' to describe factors such as 'stress', 'fatigue' and 'emotion' (McCoy et al., 2020). Some studies classified 'Human Factors' separately to 'system factors' (Jang & Lee, 2017) or 'teamwork'. (Alquwez et al., 2019; Huang et al., 2020; Mbuthia & Moleki, 2019; Raymond et al., 2017; Usher et al., 2017) This lack of shared safety language represents a barrier which is likely impeding integration of HF in the healthcare setting. Bowie and Catchpole (2021) have outlined how HF professionals can spend significant amounts of time and energy challenging the myths and misunderstandings, which continue to prevail, particularly amongst key groups and leaders (Catchpole et al., 2021). Education provided in the absence of a shared language, is likely to propagate existing misunderstandings around HF.

Utilisation of HF expertise may help overcome some of these challenges. Collaboration of HF experts with academic and clinical staff could represent an opportunity to optimise patient safety curriculum design. Such collaboration could also help develop a shared safety language while enhancing HF experts' understanding of 'work as done' in frontline healthcare. Negotiating a shared language between actors in healthcare will help draw on the strengths of multiple ways of thinking.

4.2. Tools and technologies

In addition to a lack of HF terminology, there was an absence of HF-based Tools and Technologies across the studies. This represents a barrier to HF implementation. Where interventions focused on HF, there was a lack of suitable HF competency based assessment tools. Only two studies involved surveys which had a named focus on HF. Wai et al (2020) used a modified Human Factors Attitude survey (Wai et al., 2020) as one of a selection of instruments, while Love and Varghese (2020) used the Human Factors Skills for Healthcare Instrument (HuFSHI) (Love & Zac-Varghese, 2020). Both these tools focus on non-technical skills (Reedy, Lavelle, Simpson, & Anderson, 2017; Wai et al., 2020) and do not assess the full scope of HF.

Previous work has highlighted the importance of using HF competency driven outcomes as framework for curriculum development (Vosper & Hignett, 2018) (Vosper et al., 2018). Without this, development of robust HF understanding and its applications to clinical practice is likely to remain elusive. The WHO Multi-professional Curriculum Guide (2011) was cited across several of the selected publications. (Bahadur et al., 2018; Bohomol, 2019; Jang & Lee, 2017; Mbuthia & Moleki, 2019; Usher et al., 2017; Wai et al., 2020; White et al., 2016) Issues have been identified however in relation to the presentation of HF in this guide (Sujan et al., 2019; Vosper & Hignett, 2018). Guidance is not presented on how to teach HF principles while ensuring that learners develop relevant patient safety competencies (Vosper & Hignett, 2018). New guidelines which contain clear and robust HF based competency frameworks are therefore needed to underpin future educational initiatives. It is encouraging to note that 'The review and expansion of the WHO curriculum guide' is listed as an action under the current WHO Patient Safety Plan (2021–2030) (WHO, 2021). This may represent an opportunity for implementation of HF in healthcare curricula. Given the demonstrated influence of the 2011 Curriculum Guide (WHO, 2011), inclusion of a HF competency framework along with implementation guidelines could have considerable impact.

4.3. Tasks

Where task-based interventions were utilised, the focus was predominantly on CRM or NTS training and not on the full scope of HF including systems engineering. This finding supports observations by Vosper & Hignett (2018) who noted an absence of appropriate assessment tools and widespread conflation between Human Factors and non-technical skills training (Vosper & Hignett, 2018; Vosper et al., 2018). In relation to CRM or NTS training, Catchpole et al. (2021) outline how 'There is no doubt that all are valuable but fail when applied without consideration of the wider systems in which they will be used'. This confusion around what does and does not constitute HF training is likely exacerbated by the problem of lack of shared terminology and expertise.

4.4. Environmental and socio-organisational factors

Local organisational barriers identified at faculty level included perceived lack of support, with excessive academic burden (Jang & Lee, 2017) as well as lack of prioritisation of PS teaching (Bahadur et al., 2018). Organisational impacts at this level can undermine environmental safety culture. Vosper & Hignett (2018) looked at

the impact of a 'zero-tolerance approach' to error which can exist in undergraduate pharmacy education. They described a resulting risk averse culture which can adversely impact development of skills which could foster resilient healthcare systems (Helen & Sue, 2017).

White et al. (2016 identified positive organisational support at faculty level as key to embedding safety science in an undergraduate nursing programme. This ability for organisations to collaborate with external stakeholders was highlighted as a driver of positive change. The authors describe how organisational collaboration with education, patient safety and governance teams at local hospitals ensured both 'real world perspective and stakeholder support' (White et al., 2016). Interdisciplinary organisational collaboration is also necessary for development of successful IPE programmes. IPE has been identified as an ideal vehicle for PS eduation (WHO, 2021). Delivery in line with current WHO strategic objectives (WHO, 2021) will require organisations which demonstrate the ability and desire to collaborate.

Findings of this review point to a disconnect between academic and clinical settings in the context of PS education. Several studies emphasised the need for increased organisational collaboration between academic and clinical settings with respect to PS teaching (Hanson et al., 2020; Huang et al., 2020; Jang & Lee, 2017; Love & Zac-Varghese, 2020; Mbuthia & Moleki, 2019; Rudolphi et al., 2019; Usher et al., 2017). This is in agreement with Vosper & Hignett (2018) who refer to 'the importance of how educators work with practice providers to ensure patient safety skills are appropriately developed' . Connectivity could yield benefits for both academic and clinical preceptors. In addition to supporting the formal curriculum, such collaboration holds potential to positively impact both the informal and hidden curricula.

At national level, educational accreditation bodies, and the professional regulators who influence them, emerged as important drivers of curricular change (Alquwez et al., 2019; Beekman et al., 2019; Helen & Sue, 2017; McCoy et al., 2020). Development of regulatory professional core competency frameworks which incorporate Human Factors principles could therefore act as a driver of future educational initiatives. National legislation was also presented as a powerful influencer of safety culture. From the pharmacy perspective, overarching legal frameworks which criminalise pharmacist dispensing errors in the UK were identified as promoting fear based attitudes within the profession (Helen & Sue, 2017).

At international level, strategies developed and promoted by the World Health Organisation have demonstrated widespread influence globally. This is illustrated by the widespread reach of the 2011 WHO Patient Safety Curriculum Guide (multi-professional edition) (WHO, 2011).

The components of 'Persons', 'Environmental factors ', 'Tools', and 'Tasks' should not be viewed in isolation but as interconnected work system elements (Holden & Carayon, 2021). Associated impacts carry potential for both positive and negative influence on patient safety education. If utilised to effect, they could represent powerful drivers of change.

4.5. HF and activity theory

The complexity of Human Factors in healthcare can be understood as many different activity systems interacting together. In a depiction of expansive learning at work, Engestrom has presented the following five central principles of activity theory: activity system as unit of analysis, multi-voicedness of activity, historicity of activity, contradictions as driving force of change in activity, and expansive cycles as possible form of transformation in activity (Engeström, 2001). These principles may be related to the challenges encountered by the evolving discipline of Human Factors in healthcare when conceptualised in this way. Engestrom has described the individual activity systems in terms of subjects, tools, objects of activity, community, rules, division of labour. The PETT Scan components of Persons, Environment, Tools and Tasks as presented in this review might also be viewed through this paradigm.

Some current challenges to HF expansion into healthcare can be viewed as opportunities. Differing perspectives may be interpreted as a healthy indicator of dynamic and evolving systems and a positive driver of innovation and change (Engeström & Pyörälä, 2021). As contradictions of an activity system are aggravated, individuals may begin to question existing norms. In some cases, this 'escalates into collaborative envisioning and a deliberate collective change effort' (Engeström, 2001).

Language is central to activity theory (Reunamo & Nurmilaakso, 2007). Activity theorists have highlighted the necessity for shared language in effective negotiation between actors within healthcare (Engeström & Pyörälä, 2021). A lack of shared safety language has been highlighted as a barrier to HF application to patient safety. There are observable tensions as HF evolves within healthcare. Activity theorists describe 'multivoicedness' as a positive and healthy sign of dynamic and evolving systems. There is the belief that while contradications can create 'disturbances and conflicts' they also have the capacity to stimulate 'innovation and local change' (Engeström & Pyörälä, 2021). A deepened understanding of the language of healthcare can help further the work of Human Factors in patient safety.

Engeström, Y. & Pyörälä (2020) (Engeström & Pyörälä, 2021) also emphasise the value of clinical preceptors as mentors and outline how 'all medical practitioners in workplaces become medical educators' (Engeström & Pyörälä, 2021). Robust undergraduate education would help equip future healthcare professionals with the necessary tools to support the evolution of HF within healthcare.

4.6. Strengths and limitations

Only published studies were included in the review, therefore this work does not include a comprehensive curricular overview of healthcare programmes and HF. Coding of data to the PETT Scan headings was conducted by the first author and reviewed by the research team. Inter-rater reliability was not conducted as part of the PETT Scan data extraction process, representing a limitation. This review has however looked across all healthcare disciplines and contributes to the potential to use IPE as an educational opportunity to address HF and PS in healthcare curricula.

5. Conclusion

This review sought to identify the extent to which HF is currently reported in the context of undergraduate healthcare curricula, and to characterise how it is reported using a HF systems model (SEIPS 101). Findings illustrate increased reporting of HF in the context of undergraduate healthcare curricula since a previous published literature review in the area. There is a vision that HF should become as integral as basic sciences to healthcare (Anon, 2021). This aligns with increasing global emphasis on the value of applying HF principles to improve patient safety (Waterson & Catchpole, 2016; WHO, 2021).

SEIPS 101[6] was used as a tool to help characterise how HF was reported in included studies.

Barriers and opportunities for HF implementation in undergraduate curricula were identified under the headings of people, environment, tools and tasks. Identified barriers included a lack of shared language concerning HF and a lack of both faculty and clinical preceptor expertise. Task based educational interventions were predominantly based on 'non-technical skills' or CRM training rather than the full scope of HF. Where HF was taught, robust competency-based assessment tools were not used to measure learning. Also lacking was a suitable framework to support curriculum development.

Influential environmental and socio-organisational factors may represent opportunities for HF curricular development. Promoting collaboration between HF experts, faculty and clinical personnel could enhance the formal, informal and hidden curricula. Development of regulatory professional core competency frameworks incorporating HF principles

may help drive future educational initiatives. The 2011 WHO curriculum guide was widely cited across publications. (WHO, 2011) An implementation guide based on a HF competency framework would support implementation in healthcare education.

If healthcare organisations are to move beyond a fixation on human error and lack of systems thinking, it will require healthcare professionals with an understanding and appreciation of HF principles. HF represents an excellent framework for delivery of undergraduate Patient Safety education (CIEHF, 2018; Vosper & Hignett, 2018; WHO, 2021).

Implications of research

HF represents an excellent framework for delivery of undergraduate Patient Safety education (CIEHF, 2018; Vosper & Hignett, 2018; WHO, 2021). Findings of this review illustrate an increase in reporting of HF in the context of undergraduate healthcare curricula, however the overall body of research on the topic remains low. Use of SEIPS 101 as framework in this review has helped identify current barriers and opportunities which relate to 'people' 'environment' 'tools' and 'tasks' (Holden & Carayon, 2021). Awareness of these factors can inform future educational initiatives in patient safety education.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix 1. SEIPS 101 data

	Persons	Environment/Organisation	Tools and tech	Tasks
Allen et al. (2018)	Study found that students' perceptions of HF training is limited; faculty expertise not discussed;	Describe educational environment where 'the role of HF training is still developing' Currently no formal training in HF at this institution; aim to set up regular teaching programme in HF;	Pre-intervention questionnaire assessing students' understanding of and attitudes towards human factors and perceived relevance to their careers; detail on scope of questionnaires not presented. HF competencies not discussed; session aimed at highlighting areas of human factors training (detail on content not provided); post information questionnaire to gauge students' change in attitudes and perceptions. Assessment not HF competency framework;	Participation in HF training session (content not detailed); Pre and post intervention questionnaires; HF awareness session (no evidence of use of HF competency framework)
Alquwez et al.(2019)	HF described in context H-PEPSS only; Human Factors terminology not utilised;	Student exposure to clinical environment described as potential threat to patient safety; Educational institutions driven by national accreditation standards which recommend yearly PS culture assessment at healthcare institutions; Authors perceive an increasingly strong emphasis on PS education in Saudi Arabia	H-PEPSS competency domains - not a HF tool; H-PEPSS competency domains address HF separately to communication, teamwork; self reporting used therefore subjective measurement; authors link H-PEPSS to WHO guide;	Self-reported PS competency using H-PEPSS.
Backhouse and Malik (2019)	HF described in context NTS. Faculty expertise described as general barrier to PS teaching but as limitation of HF training here.	Direction set by GMC and Health Education England to prioritise education and training as the means to improve PS across healthcare systems	Gamification with escape room. Storytelling elements described. Focus on NTS only. No HF based assessment tool.	Escape room (not HF focused). Main focus on teamwork and communication (NTS).Didactic HF training provided but no evidence of faculty expertise. How is HF knowledge assessed?
Bahadur et al. (2018)	Human Factors described separately to system factors; participants demonstrate lack of PS knowledge;	Lack of incident reporting pointing to low safety culture organisation (hospital); PS education not yet prioritised in undergraduate education (university); lack of senior leadership support perceived by some participants as barrier to PS curriculum implementation;	Authors highlight lack of evidence based strategies to underpin PS education; WHO guide presented as a framework;	Focus group; understanding of HF unclear - focus on PS generally
Beekman et al. (2019)	HF language not used -HF described separately from communication; Researcher focus on PS curriculum development (HF not a central theme); authors mention adverse event reporting, system factors and safety culture; faculty involved in intervention reported to have PS expertise;	Variation in PS curricula highlighted; Graduate Medical Education accreditation body has recognised need for PS education; Association of American Medical Colleges has included identifying systems failure and contributing to culture of safety as one of 13 core 'enstrustable professional activities' required for entering residency.	SAFE framework as structure to formulate experience; 11 item post intervention questionnaire (not HF tools);	Two PS morning report sessions held; Short didactic session of key safety concept followed by discussion of PS cases; each student presented one case; Discuss domains of PS using SAFE framework;

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Bohomol (2019)	Lack of faculty expertise described as barrier;	Authors discuss barriers to PS curriculum implementation including lack of government commitment, financial resources, lack of evaluation tools, knowledge and ability (faculty expertise)	Research uses WHO guide as framework - issues here in relation to HF; WHO guide used as framework for questionnaire design and data analysis; WHO guide presented as instrumental resource to guide PS curricular change (established issues with guide in relation to HF);	
Caro-Rojas (2018)	HF described in context non-technical skills only (communication); faculty expertise not discussed	Interprofessional focus with medical and pharmacy student involvement;	Not detailed. No evidence of use of HF based competency framework	Likely a roleplay exercise (scant detail) with focus on communication skills;
Gordon and Parakh (2017)	Expertise of academic advisors in IR is unclear.	There is recognition that incident reporting education is important, but the current health service environment (globally) means that the level of training and education in practice is very poor; Perceptions of students being watched (by organisation)	WHO curriculum guide used to underpin work - however recognised flaws with this in relation to HF understanding. Confusion around meaning of HF (framed as NTS). No HF based assessment tool to measure learning.	Unclear how HF knowledge is assessed
Gordon et al. (2017)	Author describes how NTS represents a 'small part of HF'; describes problems with confusion of HF with 'human elements'; research focus here is on NTS (impact of IPE based simulation training on acquisition of NTS and hence safety); Interprofessional cohort (included qualified doctors, pharmacists and OT as well as undergraduates (medical and nursing students); faculty PS expertise not specified;	Describe 'increasing deployment of interprofessional simulation education that aims to achieve NTS learning'; discuss inter-group contact with 'perceptions of threats and associated anxieties'; Discuss 'concept of social identity' and 'how individuals interact differently between the members of the ingroup and outgroup'	Study completed within wider context of TINSELS programme (focus is NTS); programme designed using SECTORS model (NTS focus as opposed to broader HF scope); Post intervention focus groups with thematic analysis; Anxiety and uncertainty management theory (AUM) as theoretical framework;	Three-session simulation-based intervention which took place in simulation suite; focus groups following completion of all elements of programme; focus was on 'NTS acquisition within the context of interprofessional simulation training' (rather than HF)
Hanson et al. (2020)	HF terminology/language not utilised; research focus is on communication (NTS) rather than HF; faculty expertise not discussed;	Discuss how hierarchical clinical environment can negatively impact student confidence and communication; Lack of consistency between hospital work-practices and what is taught in classroom can negatively impact worker wellbeing as well as patient safety; poor organisational safety culture indicated by fear of speaking up;	PACE and CUSS frameworks (focus on NTS rather that HF); ' video by Martin Bromiley	Students view video by Martin Bromiley;; PACE and CUSS frameworks utilised (for communication skills); 10 min role play where students are asked to complete task which is outside their current scope of practice; post intervention survey completed by students (no indication that this is based on HF competency framework); semi structure interviews carried out: focus on 'speaking up for safety' (NTS based);
Huang et al. (2020)	HF described in H-PEPSS context only; HF language/terminology not in use; Lack of Preceptor consistency in handling PS described as a problem;	No formal PS undergraduate nursing curriculum in China; evidence of increasing emphasis being placed on explicit PS competence for under-graduate nursing; report hierarchical power dynamics which make nursing students less likely to raise concerns; undergraduates receive most PS knowledge from pre-practice education at teaching hospitals (hidden curriculum);	H-PEPSS (Chinese version) - not HF based competency framework;	Self reported PS competency using H-PEPSS survey
Ibrahim et al. (2017)	interprofessional education: 3rd year pharmacy and med students; faculty expertise not discussed;	Workshop originally uni-professional. Authors describe how addition of pharmacy educator enhanced the curriculum	Grey's anatomy episode portraying medical error. Mini lectures; HF included in course content however no evidence that content aligns with HF competency framework; Pre survey created by investigators - no detail on inclusion of HF competencies; Healthcare Professionals Patient Safety Assessment Curriculum Survey (HPPSACS) - not a HF tool (self reporting tool);	Mini lecture, Grey's anatomy episode portraying medical error, group work, pre and post intervention surveys (not HF competency based); Focus on error reporting; HF content specified;

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Jang & Lee (2017)	HF language not used - Human Factors reported separately to system factors; Faculty expertise gap highlighted (PS and HF). Participants' lack of understanding of HF highlighted.	Clinical environment identified as important source of learning (hidden curriculum) - but challenged by lack of resources; reluctance by nurse educators to report incidents indication poor safety culture/environment; Connection between academic and clinical settings emphasised as important for PS education; organisational factors (e.g. Excessive academic burden) amongst perceived barriers to PS education	PSCSC and WHO guide presented as instruments -not underpinned by HF principles; IR highlighted as important means of improving PS; QSEN framework used (not HF based framework). No HF based assessment tool.	Authors emphasise that training of educators is required 'especially' in area of HF
Love & Zac-Varghese (2020)	Language - HF described in context NTS only; faculty expertise in HF not explicit	Final clinical placement was undertaken by final year med students (having passed final exams) - serves a preparatory session immediately prior to employment as junior doctor (bridging session between student and professional phases) Transition from university student to professional within clinical environment highlighted as risky for PS	HuFSHI (Human Factors Skills for Healthcare Instrument - a self reporting tool which addresses non-technical skill elements; HuFSHI tool is self-reported (not an objective measurement); introductory lecture included a video 'Just a routine operation by Martin Bromiley';	Didactic lecture introducing HF - contents of this lecture material not detailed; focus of simulation tasks is NTS; Students watch video by Martin Bromiley; HuFSHI completed by students pre and post workshop (self reported competence, NTS focus)
Mbuthia & Moleki (2019)	HF terminology not in use; students report lack of consistency in PS practices preceptors in clinical setting;	Students report low familiarity with reporting adverse events indicating low organisational safety culture; lack of resources (time) viewed as challenge for PS education in clinical environment; Authors highlight that collaboration between academia and clinical settings would benefit PS education	H-PEPSS tool -Not HF tool; H-PEPSS self-reporting tool (not objective measurement)	Self-reported PS competency using H-PEPSS tool
McCoy et al. (2020)	HF language not used - Human Factors described in terms such as 'stress', 'Fatigue', 'emotion'; faculty expertise in PS not discussed;	IPE part of accreditation standards (Liaison Committee on Medical Education); intervention provided while students on clinical placement at Federally Qualified Health Centres; Organisational link apparent between faculty and clinical placement environment (FQHC)	TeamSTEPPS strategies used then designing module for four short digital case studies; competencies listed for each case study (identification of system failures and contribute to culture of safety included as competency); Case 3 is named 'Human Factors errors'(but refers to stress, overwork i.e. 'factors of the human'; other tools include SBAR, CUS, I'M SAFE and DESC (focus on communication skills); HF competency framework not used;	Four digital case studies (case study 3 demonstrates conflation between HF and 'factors of the human'; 11 assessment questions answered during case study (not HF based); critical thinking discussion questions and post test questions (both include 'identification of human factors that contribute to medical error'; (confusion around HF language)
Partecke et al. (2016)	HF terminology/language not in use; faculty member training specified but not explicit whether this involved HF; medical and nursing students (IPE);	Stereotypes of team member roles described as cause of conflict (in context IPE); Upon project completion, an interdisciplinary working group was developed to further develop IPE concept across multiple institutions within the organisation	Described competencies not underpinned by HF framework; learning objectives align with NTS only (a subset of HF); 4CID (four-component instructional design model) used as framework for course content development (not HF framework); CRM approach stated as reference work for the interprofessional design (CRM does not equate with HF);	Tasks described do not indicate use of HF principles
Raymond et al. (2017)	Discussion includes ideas which align with Human Factors principles; Between 51% and 61% of students expressed that there is consistency demonstrated by preceptors in dealing with PS;	Global lack of research in PS education highlighted; results indicate improved climate for incident reporting (improved safety culture); describe lack of preceptor consistency in the clinical environment; Students describe negative impact of organisational hierarchy on PS; recommend education initiatives aimed at bridging transition between academic and clinical settings;	H-PEPSS (adapted version) - not a HF tool. Self-reporting tool therefore subjective; HF referred to in context of this tool; authors suggest the idea of using a simulated reporting system in conjunction with PS simulation exercise to help bridge transition to clinical setting; suggested use of anecdotes and stories to foster positive learning environment;	Self-reported PS competency using H-PEPSS tool

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Reid et al. (2018)	HF described in terms of NTS; faculty expertise in HF not referred to; no evidence of HF training for study facilitators/staff/focus group chairs; authors report that a minority of facilitators were 'complicit in perpetuating stereotypes'	Environment: hierarchical healthcare environment discussed. Tensions between professions discussed; author perception that professional stereotypes perpetuated in this IPE learning environment	HF theory training not underpinned by robust HF framework; lack of information around content of HF theory training. Subsequent activities based on NTS (teamwork) training; no HF competency based assessment tool to assess training outcomes	Participation at half day case-based IPE seminar on patient safety; Includes human factors theory (content not detailed Focus);IPE focus
Rudolphi et al. (2019)	Lack of HF terminology in use; participants' use of language (using 'human factor' to describe 'nervousness');	Authors emphasise role of ENME reporting systems in promotion of just culture;	Qualtrics survey tool for ENME reporting survey based on Eindhoven model of incident classification (not underpinned by HF principles);	ENME reporting using survey tool (learning for adverse events/near misses aligns with HF principles); Didactic seminar attended by students (content not specified)
Sujan et al. (2019)	Authors with HF expertise (CIEHF UK membership); use of HF terminology and language; participant demographics with respect to RHC expertise: expert:8, Intermediate:1, Undeclared:2; participants have contributed to literature in the field (demonstrated HF expertise); RHC/RE community within HF community	RE/RHC presented as distinct discipline (within HF); highlight need for clarity around a radical and new RHC approach versus embedding new thinking into existing methods; describe distinction of RHC based approach involving 'shift in learning to focus on everyday clinical work, moving away from counting adverse outcomes'; findings provide a breath of opinion about whether a RHC syllabus would involve a radical shift in approach versus and extension to established thinking Multidisciplinary team learning suggested;	Work underpinned by publications from recognised HF experts; online survey created by authors (experts in field). 7 questions aimed at gaining opinion of RHC curriculum development; suggested tools are HF tools (e.g. FRAM, HTA, Bow-Ties, RAG); highlighted lack of case studies providing detailed and rigorous evaluation of interventions based on RHC thinking;	7 item survey intended as first step of a consensus development exercise. Survey developed by researchers with demonstrated HF expertise;
Usher et al. (2017)	Students report lack of confidence in 'understanding human and environmental factors'; students report lack of consistency in how PS is dealt with by different preceptors; separate categorisation of 'medication safety' and 'sociocultural aspects of patient safety'; HF language not used;	Authors argue that silence/inaction is more likely in unsupportive environments; influential role of the hidden curriculum in PS education is highlighted; disconnect between classroom learning and clinical practice described; majority of students (78%) worry they will face disciplinary action if they make a serious error (indicating low organisational safety culture in clinical setting); evidence of authority gradients negatively impacting safety culture; described need to critically examine curricula to ensure gaps in safety content are identified;	H-PEPSS is a self-reporting tool therefore lacks objective measurement of PS competencies; self-reporting deemed a limitation of study; not a HF tool;	Self-reported PS competency using H-PEPSS tool
Vosper & Hignett (2018)	Authors with HF expertise (members of CIEHF UK); HF language in use; pharmacists underutilised as contributors to patient safety; describe risk-aversion as a pharmacist trait; lack of faculty expertise a barrier to implementation of PS in healthcare curricula; describe lack of shared safety language with system terminology absent from participants' discourse;	Describe: Punitive legislative framework undermining safety culture; Misconceptions around HF endemic in healthcare; zero tolerance approach to error in pharmacy curricula which would not facilitate learning from error and development of resilient systems; GPhC standards: demonstrate zero tolerance approach to error; low awareness of safety culture at institutions studied; Culture of rewarding outcome (e.g. examination) rather than process contribute to development of global attribution (e.g. shame); lack of organisational support in face of medical error can result in phenomenon of becoming 'second victims'; very little systems content in high-level course documentation. HF invariable interpreted as NTS and considered to be concerned with human error (faculty expertise)	HF presented as tool to design and improve healthcare systems; little known about what PS is currently taught in pharmacy undergraduate curricula; GPhC standards: demonstrate zero tolerance approach to error; WHO curriculum guide does not provide a clear framework for developing PS (or HF) competencies; interview and focus group schedules were developed using Eraut's theory of acquisition of professional knowledge (1994); authors highlight shared language as component of professional knowledge; constructivist grounded theory used to underpin analysis; punitive legislative framework undermining safety culture; assessment approach (e.g. OSCE) which allows error recovery may support a positive change in safety culture;	Audit course documentation for PS and HF framed as explicit outcomes; semi-structured interviews/focus groups to explore staff and student perceptions of PS and HF teaching; thematic analysis

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Wai et al.(2020)	Research focus on CRM rather than full scope of HF; faculty expertise not discussed; participants from medicine and nursing disciplines (IPE);	PS described as a challenge in context of today's increasingly complex healthcare environmet; describe a worldwide lack of evidence on how to teach teamwork (in clinical environments)	HFAS (modified Human Factors Attitude Survey) - an instrument designed to assess CRM (not HF); Ottawa Global Rating scale: a CRM (Crisis Resource Management Tool) - not a HF tool; TBL SAI (Team Based Learning Student Assessment Instrument): used to assess team based learning (not HF tool); online HF training material provided (no information on source or accreditation of this material); WHO guide used as framework for learning outcomes	Surveys undertaken by students not HF based (teamwork and CRM focused); Focus group interview - not HF focus (teamwork, simulation and group projects discussed); simulation elements based on CRM (not HF); study online materials including HF related (no background provided on source of HF based material)
White et al. (2016)	HF language not used (references to 'human error' and 'zero harm'). Authors do however refer to HF involving a systems approach. Faculty expertise in HF unclear	Organisational support: change management strategy included promoting support of senior management and 'influential colleagues'; Faculty in HF provided by 'established safety science and education training company'	Project not underpinned by HF principles. WHO guide used as framework and literature review does not yield publications from known HF experts. No HF-based assessment tool	Literature search Developing programme content Theoretical framework development Programme implementation

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