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Tertiary education in Ergonomics and Human Factors: Quo Vadis?

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Abstract:

In 2019, the Human Factors and Ergonomics (HFE) discipline turned 70; to celebrate, an international group of academics and educators have reflected on the status of HFE tertiary education across the globe. This paper draws on presentations and discussions from the 20th Triennial International Ergonomics Association (IEA) conference and considers the implications for HFE education programmes. Past, current, and future challenges are outlined and discussed with examples from different countries and programmes. This paper builds on a 2012 strategy (Dul et al., 2012), to strengthen the demand, and application, of the HFE discipline and profession. It provides a considered set of reflections, noting the range of structural issues and financial pressures within the tertiary education system that create challenges for the viability of specialist programmes such as HFE. A need exists for the broader profession to collaborate and share innovations in HFE programme development, to ensure sustainable HFE education programs.

Key words: education, human factors, ergonomics, future of ergonomics

Practitioner Statement

A range of structural issues and financial pressures exist within the tertiary education system that create challenges for the viability of specialist programmes such as HFE. A need exists for the broader profession to collaborate and share innovations in HFE programme development, to ensure sustainable HFE education programs.

1. Introduction

The scientific discipline and professional practice of Human Factors and Ergonomics (HFE) reached 70 years in 2019 (Waterson and Sell, 2006) with federated societies in over 55 countries. However, as in many academic disciplines, a range of views exist in relation to what constitutes the specialist skills and knowledge required to support future professional HFE practice.

Since its inception HFE education has faced many challenges. Few dedicated HFE courses were in existence or programmes and these were usually at postgraduate level, building on students' prior degrees in a wide range of topics such as engineering, technology, psychology, design, health, nursing, physiotherapy, medicine and management. HFE courses or programmes commonly had varying emphases. The HFE course content commonly depended on the focus of the academic programmes (e.g. in Colleges, Institutes, Schools or Departments of Health or Engineering or Design or Management) in which they were located within universities. This focus often meant that HFE courses were unable to cover the full range of areas encompassed by HFE - physical, cognitive and systems ergonomics. Recently courses have included coverage of sociotechnical systems, organisational, community or environmental ergonomics and sustainability (Brown and Legg, 2011; Martin, Legg & Brown, 2013). Prior to the beginning of the 21st century, there was no universally agreed consensus on the content of HFE educational courses or programmes.

In 2000, a consensus document was published by the International Ergonomics Association (IEA) which provided an internationally agreed list of competencies (IEA, 2001) supported by a certification programme which aimed *'to utilize a consistent approach to assessing educational based competencies of an Ergonomist …[*and*] encourage graduates to consider certification recognition as a career option'* (Caple, 2007). The IEA competencies were grouped into nine areas (units) with sub-categories (elements) and performance criteria. They were intended for use by (1) educational institutes to design HFE education courses, and (2) certification bodies (Tey and Graf, 2018).

However, the applied nature of HFE and its professional practice has shifted with rapid changes in modern working life creating new demands and opportunities for HFE both as a discipline, and in the educational requirements (Järvelin-Pasanen and Räsänen, 2018). The requirement for HFE

knowledge and skills has moved beyond traditional industrial sectors (e.g. manufacturing, military, oil & gas, mining) and is being used more widely in service sectors (Hignett and Gyi, 2018), including schools (Legg, 2006; Legg and Bennett, 2007). Employers are searching for qualified HFE professionals with accredited competences (university degree) and/or certification from recognised institutes (Górska and Kossobudzka-Górska, 2018).

Professional bodies and certification organisations have key roles as the guardians of the discipline/profession, including ensuring that practitioners are competent and follow a code of professional conduct (O'Neill, 2018). The IEA competencies have been used, interpreted, and updated by individual countries and societies to reflect changes in the application of HFE (Tey and Graf, 2018). Smith (2012) provides a comprehensive summary of certification across the world. Table 1 outlines the similarities and differences between competency frameworks for the IEA (Tey and Graf, 2018), Centre for Registration of European Ergonomists (Górska and Kossobudzka-Górska, 2018), and the Chartered Institutes of Ergonomics & Human Factors in the UK (Hignett and Gyi, 2018), Canada (Black and Village, 2018) and Mexico (Avila-Chaurand et al., 2018).

The issue of HFE professional identity is an ongoing challenge. Cuenca and Aslanides (2018), suggest that the IEA Professional Competencies and certification standards can be used to assist in the development of new educational programmes by establishing the minimal requirements for a professional education and practice. The authors also suggest that the IEA could provide support for the justification of professional level HFE education programmes. The Swedish HFE community developed a strategy to actively promote the discipline and undertook a multifaced approach to engage with the industry and the general public on a range of topical areas (Osterman et al., 2018). One IEA initiative is global ergonomics month (Robertson, et al., 2018) which aims to increase awareness of HFE across the globe through a range of formats.

In the UK, the issue of identify has been addressed through development of the Chartered Institute of Ergonomics & Human Factors (CIEHF) as the recognised national body for accrediting UK ergonomics courses (CIEHF, 2017). The Royal Charter recognises HFE as the only subject with an academic base that focuses jointly on system performance and human wellbeing (O'Neill, 2018). This challenge may need to be addressed by individual national societies as the '*IEA does not endorse people, but rather it endorses the national or regional boards that are responsible for certifying HFE specialists*' (Graf, 2018, p. 668)

In 2012, Dul et al. highlighted the need for HFE to "*strengthen the demand for and the application of, high-quality HFE (with the key elements of systems approach, design driven, and performance and well-being outcomes) for all stakeholders*" (Dul et al., 2012, p. 388). Given the ongoing interest in assuring quality in the delivery of HFE education and certification processes, a series of symposia were held at the 20th Triennial IEA Congress to share and reflect on the current status, and future opportunities, of HFE education and professional practice.

This paper aims to summarise these presentations and outline the key themes presented during these sessions, along with identifying some further actions to support sustainability of the HFE profession.

2. Current Educational Programmes

Discussions at the congress on current and proposed programmes covered a range of areas with key themes emerging which are presented as follows: course sustainability, the design of courses, delivery modes, job readiness of graduating students and course evaluation.

2.1 Course sustainability

A common international theme concerned the challenge of maintaining sustainable HFE programmes in the current tertiary education environment, which is orientated towards large scale, high volume courses. HFE courses do not fit within this model, due to the specialist nature and lower demand for education in the discipline. Numerous internationally recognised university HFE programmes have closed or changed direction, such those in Loughborough and Surrey Universities in the UK. A well-established masters HFE programme in New Zealand was closed in 2011 due to insufficient enrolment numbers required in the current tertiary fiscal environment (Legg and Stedmon, 2017; Legg and Stedmon, 2018). Small countries in particular, have often found it difficult to maintain courses and professional certification programmes (Legg and Moore, 1999). The cyclical course reviews required by Universities often provide support for the "useful" nature of the subjects being offered. These subjects are often embedded in other programmes so teaching of the HFE subjects is profitable; however, this is often insufficient to prevent the closure of an overall HFE programme as numbers are counted at programme and not subject level.

In Australia, since 1979, the teaching of HFE has been undertaken in various forms at La Trobe University, Melbourne. Changes to the programme have been undertaken to address some of the

issues concerning small numbers and niche offerings. Until 1999, the La Trobe course was only offered at postgraduate level, before changing to an undergraduate course. In 2010, following changes to degree structures and other closures of programmes across Australia, a decision was made to return to offering only a postgraduate program (Oakman and Stuckey, 2018).

In Argentina, competition to formal tertiary Ergonomics programmes arises from short course at non-accredited or low quality institutions, which has occurred due to a change national regulations (Aslanides, 2018). These short courses are marketed as providing HFE content, but do not have academic rigor or the breadth of training that would be expected from bona fide university based ergonomics programmes. The outcome of such development creates competition to more traditional tertiary HFE programmes. In addition, those completing the short courses are marketing themselves as Ergonomists, but in reality, have not met the core competencies outlined in Table 1. The tertiary education sector is a challenging environment to introduce new programs and ensure sustainability of existing ones. HFE course are exposed to some particular issues due to widespread misunderstanding of the nature and scope of HFE amongst the general public and students and academic administrators, leading to low student demand, perceptions that courses are not profitable, limited institutional support and course promotion (Legg and Stedmon, 2018). These are key challenges for HFE. However, alternative educational models (Davis, 2018) exist, where HFE has been integrated into other undergraduate and postgraduate programmes. For example, Vosper et al. (2018) propose 12 tips to embedding HFE principles in healthcare educational curricula and programmes, with a national single patient safety syllabus (including an HFE module) to be delivered through clinical regulatory bodies and education providers (NHS Improvement, 2019).

The inclusion of HFE in 'other' discipline areas was widely reported e.g. aviation human factors, industrial/organizational psychology, management systems, human resource management, industrial design, product development, rehabilitation and sport science. In Finland, HFE education has been a part of the degree programmes in Health Promotion since 2016. The degree programme educates specialists in HFE, who can design work and work environments based on scientific knowledge with the course content (over five years), corresponding to the qualification of the European Ergonomists set by Centre for Registration of European Ergonomist (CREE) (Górska and Kossobudzka-Górska, 2018; Järvelin-Pasanen and Räsänen, 2018).

One area of opportunity is the inclusion of HFE in User Experience (UX) education. However, there are differences in professional competency requirements with HFE having clearly defined (and established) competencies (IEA and UK) and a lack of 'definitive set of competencies' in UX (Furniss et al., 2018). Possible reasons for the differences are the age of the disciplines (UX is relatively new compared to HFE) and '*the diverse mix of skills and roles that make up the community, making it challenging to identify an agreed set of competencies'* (Gray et al., 2015). The relative lack of prescription regarding competencies across UX education does not imply less regard for professional competence, rather there is less agreement on what the specific individual competencies are for UX practitioners and how to ensure students are adequately equipped (Hignett & Gyi, 2015). This requires HFE to demonstrate the relevance of its methods and knowledge to achieving desired UX competence, e.g., in areas such as analytic insight (see, Furniss et al, 2018).

In contrast, challenges also arise from outside the University such as that from the UK MSc Organizational Psychology programmes. The HFE content has been downgraded within the British Psychological Society Qualification in Occupational Psychology (QOcc Psych) Stage 1 (Fletcher and McDowall, 2014) with a reduction in emphasis within accredited courses which poses an existential threat to the understanding of HFE within the organizational psychology profession (Davis, 2018).

The same existential threat is presenting in Algeria's Master of Work and Organizational Psychology programmes (Mebarki and El-Bachir, 2012), where HFE identity is being absorbed into the dominant host discipline (occupational health, psychology, etc.). This secondary position has been recognised for many years in the discipline and professions where ergonomists are usually a minority group in teaching programmes and syllabus development panels. Whilst in countries where HFE professional practice is well established some content can be ensured (even if minor) (e.g. UK; O'Neill, 2018), it may be problematic in developing countries where ergonomists do not have such a strong identify in education and professional practice.

2.2 Incorporation of HFE methods and principles in course design

It is important that HFE 'practice what it preach' in its approach to course design. A large body of HFE research and theory is devoted to ways of approaching complex design problems (Waterson & Sell, 2006; Thatcher et al 2018) through ideas such as systems thinking and user-centred design. HFE has demonstrated that good design requires listening to users, involving multiple stakeholders and drawing upon the expertise of other disciplines (e.g., Clegg, 2000). Many of these ideas are not

unique to HFE, but they underpin our mindset and ways of approaching design challenges. Discussions at the congress reinforced the value of applying specific HFE methods or principles to the problem of course design and delivery and offer practical illustrations.

One such illustration comes from the United Kingdom, Davis (2018) explains how the delivery of HFE content within the MSc Organizational Psychology at Leeds University Business School (UK) reflects the core Sociotechnical Systems Theory (STST) philosophy on which it draws. The HFE module is designed to promote multidisciplinary working, drawing students from both the MSc Organizational Psychology in addition to Engineering, Geography and Physics programmes. Students are required to work on a group accident analysis task (using HFE frameworks such as AcciMap) that necessitates the application of different disciplinary knowledge to generate practical lessons learned and guidance for presentation back to a fictitious client. A diverse student cohort facilitates cross-disciplinary knowledge sharing and demonstrates the value that different skill and knowledge sets can bring to the discussion of complex problems.

In France, Bonnardel (2018) reports that a range of colleagues from different departments and laboratories at Aix-Marseille University, including Computer Science and Management Science, contribute to the HFE programme. These multi-disciplinary inputs complement traditional ergonomic skills (e.g., work and activity analysis, risks prevention, work conditions, nuclear plants, medicine, information system architecture, user interface design and evaluation, UX design) which are core to the programme. This multi-disciplinary approach aligns with STST principles; where bringing together those from diverse backgrounds and skills to share views and expertise fosters creativity and innovation (Clegg, 2000). In another integration of systems principles in course design, Davy et al. (2018a) used Wilson's (2014) six notions of systems focus, context, interactions, holism, emergence, and embedding to inform the design of a course undertaken as part of an Ergonomics Honours degree.

Other HFE methods and approaches have been utilised in the design of HFE courses. For example, in Mexico, Avila-Chaurand et al. (2018) responded to industry needs in their development of a Master's programme. A range of evidence was collected to inform the development of the programme, including surveys of industry representatives to ascertain requirements of graduates and the expected demand. In addition, a range of international programmes were reviewed to identify different structures and subjects being taught across the globe.

Similarly, Stedmon et al. (2018) described how industry and user requirements were considered in the design of a Master program in Aviation Human Factors. The programme was targeted at engaging industry professionals and utilised a distance learning format to be completed on a part time basis to enable the participation of those employed full time. Further, the course materials were designed to recognise the professional background of students and then extend their existing knowledge.

2.3 Online and flexible course delivery

Non-traditional delivery formats such as online / distance learning courses are becoming ubiquitous across the university sector. Within HFE, formats have been developed and adopted for various purposes including providing flexibility for students (Järvelin-Pasanen and Räsänen, 2018; Stedmon et al., 2018) and enabling greater accessibility to students in a range of geographical locations (Stedmon et al., 2018; Berglund and Osvalder, 2018 Järvelin-Pasanen and Räsänen, 2018). This was particularly important when the course was aimed at particular groups such as international aviation professionals (Stedmon et al., 2018).

A further benefit of more flexible delivery of HFE programmes has been the inclusion of greater student diversity, enabling students from a range of backgrounds to enrol in the programme. This enables sharing of job relevant knowledge and experience between students and offers networking with current professionals (who may also be potential future employers) and potential opportunities for work experience or placements. For example, Hignett and Gyi (2018) report on the redesign of Loughborough University MSc Ergonomics and Human Factors programmes. These programmes shifted from a model of traditional weekly lectures and teaching activities to a block delivery approach where modules are delivered intensively over a one-week period. This change in approach increased the diversity of the student cohort in terms of age range, work experience, and professional background, and resulted in 50% more admissions than in previous years. The change in delivery format has also improved access and uptake of more part-time students from across the EU.

Stedmon et al. (2018) explain how the distance learning design of their HFE Master program was specifically designed to attract UK, EU, and international students, many of whom would have been unlikely to undertake traditional postgraduate study. The student profile includes many individuals with work experience in aviation-based organisations spread globally (e.g., major international airline companies, air traffic management providers). The global make-up of the cohort offers students an opportunity to interact with a wider range of individuals than may typically be possible

on traditional HFE courses. This benefits students' career development and opportunity to network. The part-time nature of the course also allows students to continue to progress with their current employers and to concurrently apply the knowledge and skills they have gained in their own organizations into practice. As with any distance learning or exclusively online course delivery, simply providing opportunities to interact is will not necessarily lead to interaction and creating meaningful student-student discussion is difficult (Razmerita, Kirchner, Hockerts, & Tan 2018; Oakman, 2016). Providing opportunities to support the development of communities is achievable but requires thoughtful course design to incorporate specific interaction points for students to engage with each other (Oakman, 2016) and include 'social, off-task communication' (Kreijns, Kirschner & Jochems, 2003, p349), as would occur around or outside formal learning activities in the offline world, to encourage genuine interaction and relationship formation.

A Massive Open Online Course (MOOC), 'Work and Technology on Human Terms', was developed through a collaboration of five Swedish Universities (Berglund and Osvalder, 2018; Osvalder and Berglund, 2018), and represents a novel approach to integrating ergonomics education within tertiary education courses. The MOOC is freely available online worldwide, and consists of animations, interviews with academics, practitioners and other experts, and practical case studies on core HFE topics. The MOOC has a benefit in terms of increasing the accessibility of HFE knowledge to a global audience, but its development also provided a set of digital assets and materials for use in traditional university programmes. Across the five universities, the MOOC materials were integrated in different ways: as voluntary supplementary learning material, as scheduled activities for self-directed study, and as a mandatory material which was discussed as part of seminars. Thus, it represents material that is flexible for users and for the universities which adopt it as part of formal courses. This experience demonstrates the value of collaborative approaches to course development and suggests that the development of MOOCs may also contribute to course sustainability by offering digital learning materials that can be integrated across multiple courses in a flexible way. The production of digital resources for use in MOOCs or traditional university courses is not without cost, both in terms of academic staff time to develop the core material, but also related production costs to achieve video and visual content that is of high quality in order to engage a public audience

2.4 Job readiness

The applied nature of HFE, the importance of delivering high quality HFE services following graduation, competencies beyond knowledge, and skills in HFE theories, principles and methods are important inclusions in course design. Bonnardel (2018) and Davis (2018) both reported an explicit

focus on the inclusion of a range of business skills, tasks and tools within their HFE teaching and assessment activities. These activities provide an opportunity for students to connect conceptual and methodological knowledge and skills with real world applications. For example, Davis (2018) integrated a STST analysis of the BP Deepwater Horizon oil spill in the course design along with the requirement for a consultancy report and client pitch as the output.

Oakman and Stuckey (2018) report on the need to prepare graduates for a range of potential industries. They report on the reduction in employment opportunities for their graduates following the contraction of the Australian mining and manufacturing sector. An over-reliance on single areas of practice or industries can pose a risk to the employability of HFE graduates and illustrates the need for educators to consider emerging trends that may offer future employment opportunities (e.g., humanoid robotics, artificial intelligence).

Looking beyond educators' own preconceptions of the skills that employers are seeking of HFE graduates has been reflected in the development of many HFE programmes. For example, Rose and Österman (2018) discuss the mapping exercises undertaken to inform the development of an International Master's Programme in Ergonomics at a Technical University in Sweden, which involved reviewing the societal needs for the programme, the employer expectations, and views of HFE graduates and their perceptions on the gaps in knowledge and skills in existing curricula. Similarly Read, Beanland & Salmon (2018) designed a research phase to engage with industry stakeholders prior to course design. This exercise was undertaken to inform potential course content, mode of delivery, and required knowledge and skills for a new programme to ensure it would meet the emerging challenges facing industry.

2.5 Course evaluation

Evaluating the effectiveness of courses is good practice, particularly in relation to novel course delivery modes. For example, Berglund and Osvalder (2018) conducted an evaluation of their MOOC (described earlier) using questionnaires and qualitative interviews with their current students. This was a more in-depth research exercise than is typically undertaken as part of a course evaluation, reflecting the need for deeper insights in the earlier stages of programme design, or redesign, than may be required in the refinement of a more established course or programme. The evaluation activity delivered valuable insights for the programme team, identifying that whilst students found the MOOC a good general introduction to ergonomics, students wanted more in-depth theoretical knowledge. This poses a challenge for the programme team as the cohort is highly diverse in their

disciplinary background with a range of student capabilities and preferences for learning materials. The evaluation illustrates the challenges that HFE educators can face when attempting to scale up modules and deliver them to larger, non-specialist HFE or multi-disciplinary cohorts (see also Davis, 2018).

Davy et al. (2018a) discuss the evaluation of a service-learning course, designed as part of their HFE programme delivered in South Africa, to provide students with practical experience by applying their knowledge to an applied problem in a community-based service. Students provided structured reflections on the service-learning component of their course. The analysis demonstrated that the task and training enhanced the ability of the students to practically apply the theory however, students reported a lack of awareness as to the social benefit that users of the community-based service would gain as a result of their work. Davy et al. (2018a) used the evaluation to identify potential improvements to the framing and introduction of the task to improve student engagement - in particular that the students' recommendations would be considered by the service's management. Additional in-class preparation prior to the fieldwork also enabled co-construction and feasibility assessments of student recommendations.

Alumni can also provide valuable insights into the applicability of course content for graduates preparing for roles in different industries. For example, Järvelin-Pasanen and Räsänen (2018) collected survey data from alumni to evaluate perceptions of utility and breadth of coverage once graduates had gained work experience. Oakman (2016) also interviewed graduates to identify where improvements could be made to the program, and in what areas graduates were being employed.

3. Future Challenges and Opportunities

Discussions at the congress extended beyond current programmes to consider the future of HFE education. The future of education for HFE professionals needs to reflect the successes of the past but to also anticipate the future challenges and incorporate these into programme design. For example, the ability for students to be located anywhere across the globe whilst studying provides an opportunity but also affords some challenges in ensuring that culturally specific issues are addressed. We also need to ensure that programme content keeps pace with the increasingly complex nature of the problems that ergonomists will be asked to address and the tools available to them to undertake such work (Thatcher et al, 2017; Davis, Hughes, McKay, Robinson & van der Wal, 2019).

Todd (2018) raised the issue of low and middle income countries (LMICs) and the need for high quality programmes relevant to the country of application. Only 15% of IEA federated society countries are defined as low and middle income economies, in contrast with a 45% representation for higher income countries. Davey (2018b) described the achievements on the $BRICS_{plus}$ network (Brazil, Russia, India, China and South Africa) which was created to support countries to enhance their HFE teaching, research and practice. A key issue is the limited understanding of the actual needs of LMICs, as outlined many decades ago by Wisner (1985) and Moray (1995) who argued that recognition of local and indigenous solutions should take preference over global or Westernized solutions. More recently, Thatcher and colleagues (2017) argued that little has been done to address issues relating to LMICS, and that the Dul *et al., (*2012) future state of ergonomics opinion paper only provided a "*cursory engagement with ergonomics requirements for emerging and under-developed countries*" (p 203).

As discussed previously, programme delivery has already shifted from traditional face to face offerings to online and even Massive Open Online Courses (MOOC) (Berglund and Osvalder, 2018). Online offerings remove some of the traditional barriers to establishing programmes because the available student pool is far greater than with a face to face offering (Kreijns et. al., 2003). However, certain challenges arise in developing practical skills and important networking opportunities that can be difficult to achieve with online courses(Oakman, 2016).

Aoki (2018) discussed challenges not in relation not to course sustainability but with the sharing of the professional certification processes. Aoki outlined the extensive development process of the Japanese certification process and highlighted some challenges in sharing this with other Asian countries, potentially due to language barriers, although the examination process is available in English and Japanese. Aoki (2018) described the extensive development process of the Japanese certification process and highlighted some challenges in sharing this with other Asian countries, potentially due to language barriers although the examination process is available in English and Japanese.

To support a thriving international HFE community, it will be important to utilise contemporary communication methods to facilitate and support communities of practice. The current paper does not cover all programs across the globe, and focuses on those which were covered during the IEA conference, and is a limitation of the paper; however, the intent is to raise a broad range of issues in

HFE education to promote discussion and potential future options to ensure a healthy and vibrant future for the profession.

4. Conclusion

A range of issues in the tertiary education system create challenges in coordinating the development and maintenance of specialist academic programmes, including HFE. A range of approaches have been outlined, with varying levels of success, that different countries have used to ensure the viability of their HFE programmes.

In many cases, HFE is integrated into other academic programmes across a range of disciplines. Students may not study HFE in depth and not identify as ergonomists but they gain an appreciation of the methods and approaches to problems that can be solved using HFE principles and methods. Whilst some HFE professionals may argue that this approach compromises the identity of HFE programmes, it also offers a lifeline for the survival of programmes which may otherwise be closed.

The present paper has succeeded in its aim of collating the disparate experiences of a wide range of international HFE educators. The next step should be to build on this and develop a strategy to ensure future sustainability of HFE educational programmes. Further discussions are needed, through global networks, about HFE competencies and how to support and develop the HFE discipline to ensure that there are sufficient high-quality education programmes to train future generations of HFE professionals. The authors hope that the present paper will stimulate further discussion on the sustainability, content and delivery of HFE education and encourage readers to reflect and contribute to this important debate through their networks and associations and at future IEA conferences.

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Declaration of Interest

The authors have no conflict of interest to declare.

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