IPEM Report on a Clinical & Scientific Computing Workforce Survey 2019: Patterns of Computing within MP&CE

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Executive Summary

The IPEM Workforce Intelligence Unit (WIU) exists to provide accurate data on Medical Physics & Clinical Engineering (MP&CE) services and staffing[1]. Clinical and Scientific Computing (CSC) is a small primary MP&CE specialism but computing activities are common to all. In this article we use CSC activities to cluster the respondents of a survey, to try to provide clear insight into the CSC contribution.

The result of this clustering shows that CSC activities do not fall alongside traditional MP&CE specialisms, but interact with all. This provides scope for cross speciality training and development, together with the potential for shared job descriptions. The survey results also demonstrate the variety of skills that CSC staff bring to MP&CE and show that a significant proportion staff perform these CSC activities outside of their job description. These CSC roles are predominately filled by those with a physics educational background, with additional, often informal, computing training. The rapid growth in demand for health IT innovation and networking suggests that this approach may not be the most effective way to fill positions. The Clinical Bioinformatics (Physical Sciences) STP course is now available and MP&CE CSC specialists have had significant input into its curriculum. This course, although intended to fill the training gap, is in its infancy and the term ‘bioinformatics’ is imprecise and poorly understood. The course family is designed to support genomics and informatics needs, as well as those of MP&CE but this wide scope poses challenges with both the recruitment and deployment of trainees.

The provision of formal training opportunities needs to be carefully monitored. The existence of CSC positions needs to be reflected in the NHS Electronic Staff Record (ESR) but to achieve this the activity needs to be clearly defined in the job descriptions and then coded as Clinical Bioinformatics in the ESR. Both these issues need to be addressed to help the WIU to better understand the need for CSC staff within MP&CE and so be positioned to make the case for sufficient training posts to meet an increasing demand.

1 Introduction

In 2015, The Informatics and Computing Special Interest Group (ICSIG), in conjunction with the WIU, ran a questionnaire to explore the involvement of Medical Physics and Clinical Engineering (MP&CE) staff in clinical and scientific computing (CSC). Responses were invited from department heads, to assess workforce issues such as grading and vacancies, and from their section leads, to assess computing activity. The results reflected the views from 27 institutions and 43 departmental groups and were reported in Scope[2]. The data represented 224 staff involved in CSC Computing, with a whole time equivalent (WTE) around half of this due to mixed roles. The results indicated that 65% of the 43 responding departments had difficulty recruiting computing staff, and 73% said they had insufficient staff resources. A subsequent survey was conducted in early 2019, to look at the activities, skills, education and training of staff involved in CSC. The previous survey was 'top-down', run via Heads of Departments, this survey was conducted 'bottom-up', using an online questionnaire targeted at individual members and we report its data here.

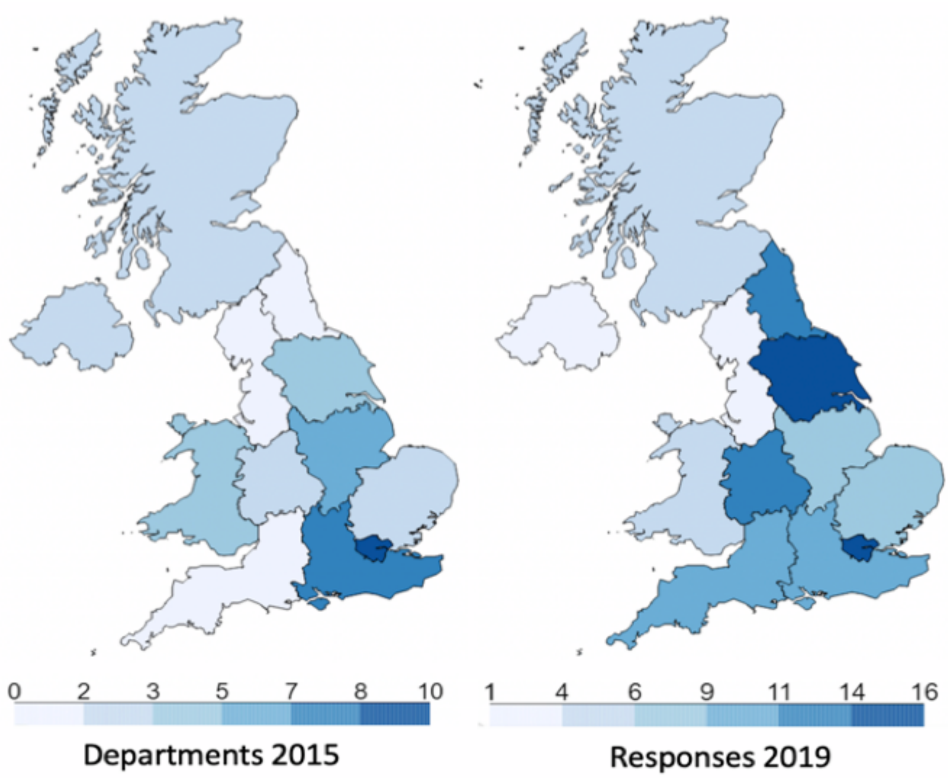

Figure 1: Choropleths showing the regional distribution of 43 responding departments (27 institutions) from the 2015 survey and 125 voluntary individual responses from the 2019 survey.

The 2019 survey attracted 125 individual responses (Figure 1) representing 45 institutions (41 NHS and 4 private). Only 19 institutions overlapped with the 2015 survey, although 21 respondents did not declare an affiliation. Two authors screened the respondents and 113 were kept for analysis, with rejections based on the role or if zero hours were indicated for computing activities.

1.1 Methods and tools

SmartSurvey was used to conduct the web survey, which ran between December 2018 and February 2019. The data was exported into Microsoft Excel by the WIU, and this was then used for data quality checks, screening and coding.

Data analysis was then performed, in Python, using the Jupyter integrated development environment (IDE). The data was exported from Excel as a comma-separated values (CSV) file, and imported into a pandas[3] Dataframe. The data was then analysed by creating a Clustermap based on specific CSC activities, see: seaborn/scipy[4]/matplotlib[5].

A clustermap[6] is a heatmap ordered using Agglomerative Hierarchical Clustering (AHC) to help identify patterns. AHC iteratively groups individual cells together into clusters, based on their distance apart. The clusters are then merged together, using a linkage criterion to define the inter-set distance, until one remains. Dendrograms along the top and left-hand side of a clustermap show the AHC output for rows and columns, with the tree heights indicating the strength of the relationship. Summary results for various other questions were then produced, broken down by primary specialism and the output clusters from the AHC.

The results of subsequent questions were then grouped both by traditional MP&CE specialisms and by clusters derived from the AHC. These results are presented as conventional heatmaps. Figures are presented using the virdis perceptually uniform colourmap with labelling using a Tol[7] Muted colour-blind safe palette. Choropleth figures were produced using Folium[8].

2 Survey Findings

2.1 Specialisms and Computing Activities

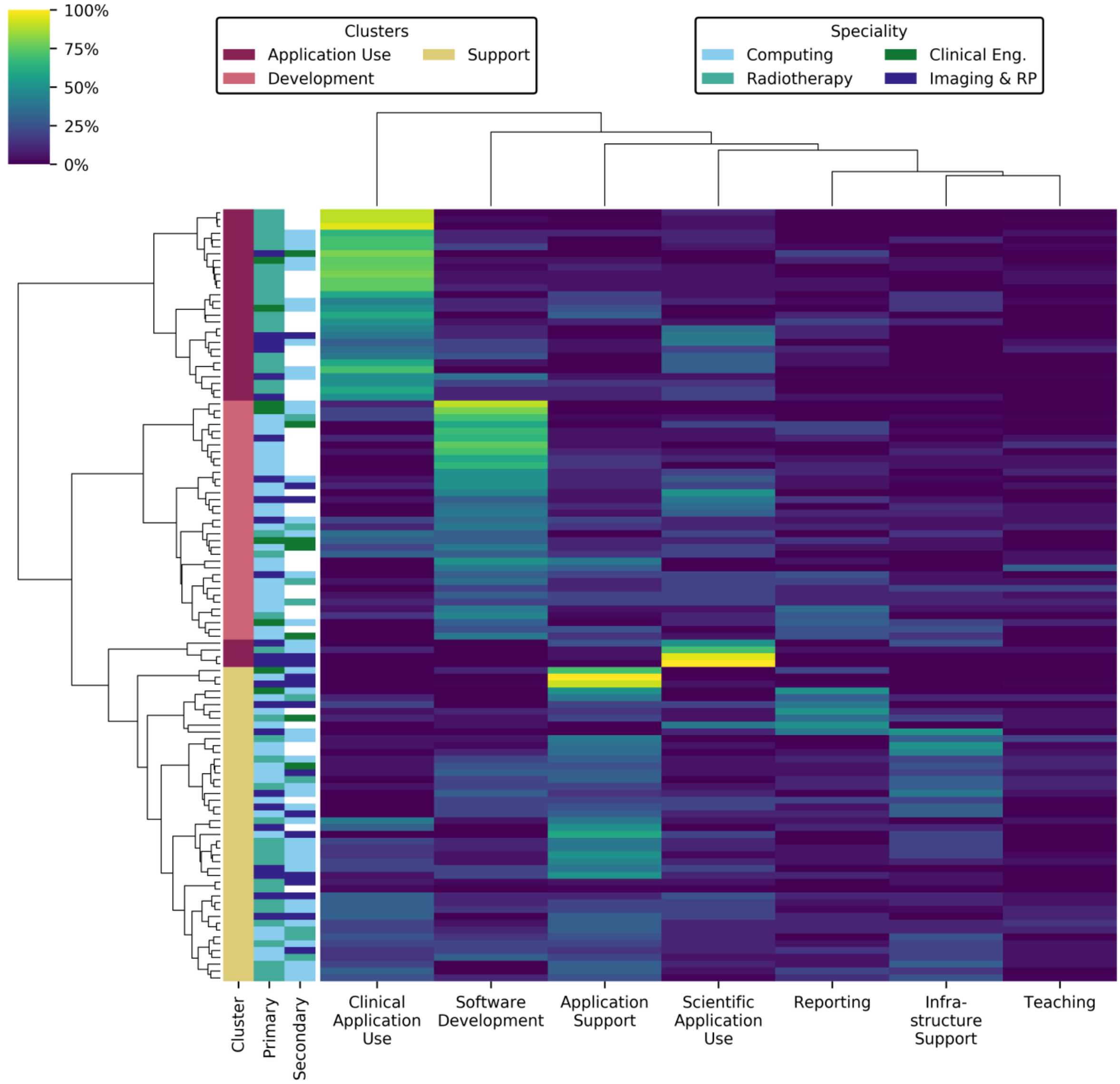

Figure 2: Clustermap (using Euclidian distance and Ward's linkage[9]) showing the percentage time spent performing each of the seven CSC activities, with rows representing individual respondents. Labels on the left show cluster, primary and secondary roles, as described in the text.

Respondents were asked for their primary and secondary MP&CE specialism, and to estimate the percentage of their time spent doing specific computing activities. Radiotherapy (RT) physics was the most common primary specialism (n = 43) followed by CSC (n = 39), Diagnostic Radiology (DR) (n = 11), Non-Ionising Imaging (NII) (n = 7), Nuclear Medicine (NM) (n = 7), Clinical Engineering (CE) (n = 4) and Clinical Measurement (CM) (n = 3) with single respondents from Radiation Protection (RP) and Rehabilitation Engineering (RE).

Figure 2 shows a clustermap of the percentage of time spent on CSC activities reported in the survey. On the left-hand side we show the primary specialism of each respondent, the secondary, if applicable, and the cluster groups revealed by the AHC. The figure is complex, but serves to illustrate the diversity of the workforce undertaking computing activities.

Starting at the top and working down, a large (n = 28) cluster, comprised mostly of RT physicists, spend the majority of their CSC time using clinical applications. Half of these have a secondary specialism. The next 35 are predominantly engaged in software development, and are largely CSC, with four of the eight CE; again around 50% have a dual specialism. Then comes a distinct cluster of four, predominantly using scientific applications. The remaining 46 are classified through application and infrastructure support activities and 85% declare two specialisms. This is the least homogenous cluster.

In further analysis we will use the terms Development, Support, and Application Users to define clusters, combining the Clinical and Scientific Application Users into one cluster. The term Application User simply references an activity and we appreciate that those using the applications will frequently also be active in supporting and developing clinical services. The first section in Table 1 provides a breakdown of the primary and secondary MP&CE specialisms in each of the clusters. It is apparent that the activities do not fall nicely along the traditional specialism divides.

Cluster		Development		Support		Application Users	
Cluster Size		35		46		32	
MP&CE Specialism							
		primary	*secondary*	*primary*	*secondary*	*primary*	*secondary*
Radiotherapy	RT	3	4	18	5	21	0
Computing	CSC	23	7	16	21	0	12
Imaging & Radiation Protection	DR	3	0	3	1	3	0
	NII	1	0	3	4	3	0
	NM	1	1	3	1	3	0
	RP	0	1	1	5	0	3
Clinical Engineering	CE	1	2	2	2	1	0
	CM	3	1	0	0	0	1
	RE	0	1	0	0	1	0
Educational Background							
Physics		19		32		25	
Engineering		8		6		2	
Computer Science		4		4		0	
Technologist		1		2		2	
Bioinformatics		2		2		0	
Other		1		0		3	
Educational level							
Level 8: PhD/DPhil		20		13		9	
Level 7: MSc/MEng		14		28		21	
Level 6: BSc/HNC/HND		1		5		2	
Professional Qualification							
HCPC Registered Clinical Scientist		23		34		24	
Register of Clinical Technologist (RCT)		1		3		3	
IPEM Associate Member		8		7		10	
MIPEM/FIPEM		14		33		18	

Table 1: summary of question responses by activity cluster

2.2 Scientific and Clinical Computing Skills

Respondents were asked to self-assess whether they had a range of CSC skills. Figure 3 shows the percentage of respondents saying they had a skill both by primary specialism and cluster. Intuitively those frequently performing an activity should have the required skills, so deficiencies within a cluster should be more meaningful than within a specialism. Unsurprisingly then, the support group showed the widest range of skills in support activities, and developers showed the greatest proportion in database, software and web development.

The Application Users cluster was largely skilled at Macro and/or Script development and scientific coding, but few claimed software development skills. This indicates a common entry point to computing within MP&CE, where academic scientific coding skills are applied in the clinical environment. The result by primary specialism shows that CSC claimed more skills overall.

The skills with the fewest respondents indicate areas for improvement. Bespoke hardware design had the fewest claimants, even amongst the 8 CE respondents.

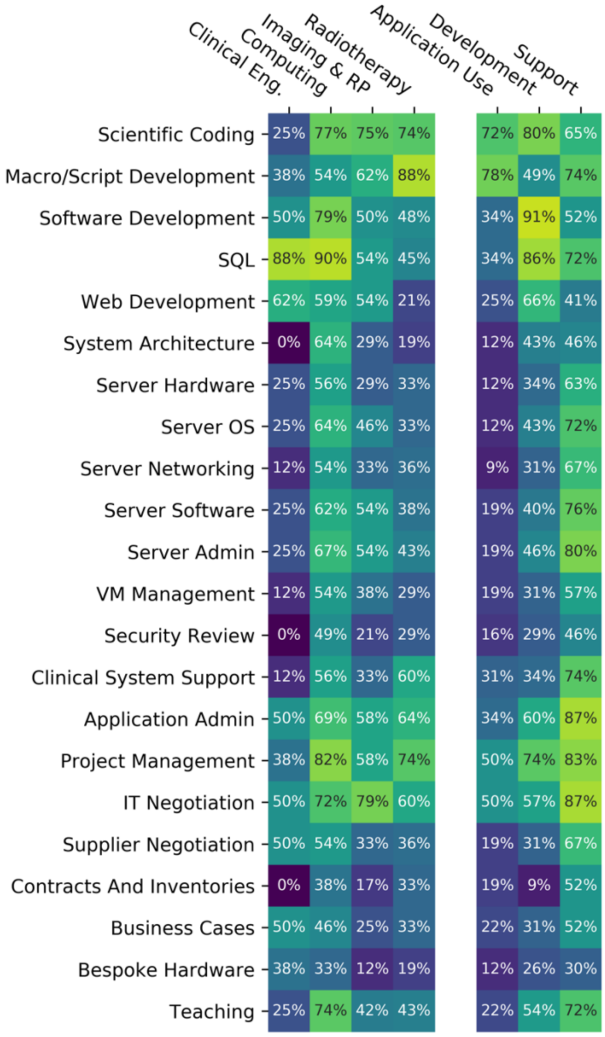

Figure 3: Heatmaps of percentage of respondents declaring they have a skill by primary role and cluster.

The most alarming general weakness was security review, with only 46% of Support and 16% of Application Users claiming they had the necessary skill. Cyber security is therefore a particular training need, especially in light of ransomware outbreaks, which appear to have risen alarmingly during the coronavirus pandemic. Good local judgements are required when cyber security changes conflict with Medical Device software upgrade policies.

Business cases and Contracts/Inventories management correlated with pay band and 90% and 80% respectively of Band 8c or 8ds had these skills. System Architecture skills were claimed by only 46% of Support and 43% of Developers, which indicates a training need.

2.3 Acquiring and developing computing skills

Skills are the product of educational background and the subsequent mix of training and self-learning. Respondents were asked for their educational background and highest qualification. Table 1, Sections 2 and 3 provide a breakdown of educational level and background. Note that the backgrounds are dominated by physics at 67% and engineering at 14%. The Development cluster has a higher proportion of level 8 (PhD) educated respondents.

Respondents were asked to estimate what percentage of their computing education was through self-learning and to rate how well their education in computing matters matched the tasks they performed. Figure 4 includes results across both specialisms and clusters and first it shows that the percentage of self-learning is high. Next it shows the CSC educational satisfaction scores (0-10) by primary specialism and cluster. Respondents were largely content, so self-directed learning is not seen as a barrier. Continuing Professional Development (CPD) is a requirement of registration and 90% of respondents were registered or working towards it so the result should perhaps not be a surprise.

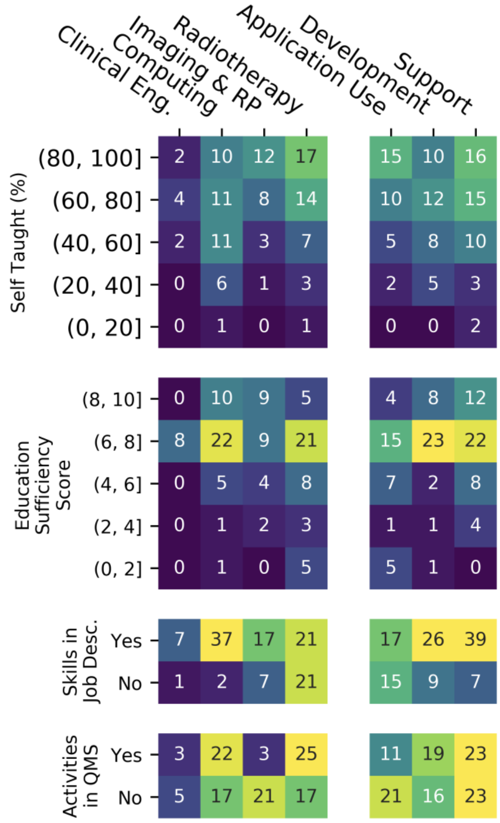

Figure 4: Heatmaps of count of responses to percentage self-taught, education sufficiency score, Skills in JD and Activities in QMS by Primary Role and Cluster.

The high pace of development within computing makes self-learning inevitable, and differences in technologies between centres mean that experience may not be readily transferable. It appears that recruiting a variety of MP&CE staff and allowing some to develop the necessary CSC skills is common. The supporting formal training pathways are problematic for CSC. The Register of Clinical Technologists (RCT) has proposed two scopes of practice, under engineering for support and under physics for development and informatics. The results of this survey indicate that this divide is artificial, but as access to computing technologist training programmes is highly desirable, this approach is welcome.

The CE Scientific Training Programme (STP) curriculum contains a *"CM and Information and Communications Technology (ICT)"* rotational module, with advanced ICT under CM and Development. The MP STP curricula contain introductory ICT within specialist modules, covering support and developmental activities. MP&CE specialist input to the Clinical Bioinformatics (CBI) (Physical Sciences) STP curriculum ensured that it provides substantive computing training for potential MP&CE trainees. However, it is grouped with CBI (Genomics) and CBI (Health Informatics) and the courses include lectures and work based rotations involving all three areas. Whilst introducing genomics expertise into the MP&CE workforce should be viewed as an opportunity, a consequence is that the CBI alumni who work in MP&CE departments require further post-registration training to familiarise them with relevant MP&CE specialisms. The title Clinical Informatics is imprecise and not well understood, making both the recruitment and deployment of trainees difficult. These issues have now been recognised by Health Education England[10]. The CBI(PS) programme does not provide the option, available in the earlier IPEM scheme, of making CSC a specialism within MP&CE. The flexible IPEM Route 2 equivalence scheme continues and provides CSC staff; in addition, the Academy for Healthcare Science (AHCS) now offers an equivalence scheme for all the STP themes, including CBI[11].

Continuing the development of MP&CE staff computing expertise requires departmental support. Respondents were asked whether their CSC activities were recognised in their Job Description (JD), and included in a formal Quality Management System (QMS). Responses are summarised in Figure 4. Only half the RT respondents said that their CSC activities were within their JD. The clusters again showed that most mis-matches were in the Application Users group. Furthermore 11 out of the 40 respondents who put CSC as their secondary specialism did not have the requirements within their JD.

60% of RT respondents indicated that their computing work was within a QMS, more than any other group. Since the late 1990s it has been a requirement that multidisciplinary QMS are used within RT. Most use ISO 9001 and many have evolved to include related CSC activity. Survey responses on QMS from the support and development clusters were 50% and 54% respectively. For in-house Medical Device manufacture, including software, ISO 13485 is appropriate, supported by the wide range of established ISO computing standards. Whilst accreditation to BS 70000 aims to cover the full range of MP&CE activities, its benefit has yet to be proven and its philosophy may conflict with the increasingly multi-disciplinary way in which clinical computing services develop. At the time of the survey, the EU Medical Device Regulations (EU MDR 2017) was still anticipated to come into effect in May 2020, mandating a QMS for MD development. Consequent governance changes[12, 13] will follow.

It is equally important that computing support activities are included within a QMS and that relationships with corporate IT and external suppliers are covered. Understanding IT service provision standards such as ITIL and the ISO 20000 family, more familiar at corporate level, can assist in building relationships with IT departments. Healthcare specific standards such as ISO 80001, the newly published 81001 and BS EN 15224:2016 are slowly evolving and need to be kept under review.

The presence of a QMS usually indicates a well organised management structure. A survey intention was to explore the extent of formal management across the CSC workforce. Respondents were asked to reveal their employing organisation and about 17.5% were sole representatives, furthermore 14% did not reveal their organisation. Even when we had several respondents from one organisation it was rarely possible to establish whether there was formal collaboration or, if present, whether it crossed traditional speciality boundaries, so providing risk reducing strategies for absence cover and more general support. For these considerations clustering is less helpful, for example, absence cover may be less critical for a developer than for support staff. The fact that management organisation was not revealed highlights some of the challenges of designing questionnaires.

3 Conclusions

Online surveys are prone to self-selection bias, with probability sampling required to produce generalizable results[14]. The survey respondents do not adequately represent all specialisms within MP&CE, particularly those in CE. By clustering on CSC activities, we have highlighted distinct groups that span MP&CE specialisms, and the survey results may generalize better within these clusters. This also draws attention to the possibility that CSC JDs can be applied across departments, rather than just within sections.

The question of how best to train and plan for CSC positions remains and a skills shortage was already indicated by the 2015 survey. Our survey indicates that CSC skills are generally self-learnt rather than formally acquired. This approach may no longer provide the most effective way to fill positions, especially given increasing complexity due to the adoption of Artificial Intelligence and Machine Learning. Formal CSC training is available via the CBI (Physical Sciences) STP. However, because it does not cover any other individual MP&CE specialisms in depth, as the earlier IPEM scheme did, so some further training will be needed in post. Unfortunately, it is not yet clear that the CBI course is dealing with the problem.

Considering the further development of CSC skills in-post, technical information is readily available online and commonly used, but professional best practice is generally harder to develop through self-directed learning. CPD courses provided by IPEM can help. ICSIG ran well subscribed workshops in 2017 on DICOM and 2018 on software development. A course on support activities was under development when ICSIG was disbanded. Departmental managers can help by encouraging staff interested in CSC activities to collaborate in service provision and support, importantly considering cross specialism collaboration. Locally posts naturally develop and this can lead to the creation of formal computing groups, so, as specialisms grow, it is important to keep JDs aligned with activities.

Whether CSC skills are developed through formal training or in-post, it is important that the role is recognised within organisations. The survey reveals that 29% of respondents had CSC as their primary specialism and 33% as a secondary one. Furthermore 27% performed CSC activities outside their JD, an unsatisfactory situation. IPEM's NHS members have Electronic Staff Records (ESRs), derived from their JD. The NHS ESR System, overseen by NHS Digital, is frequently updated, and CBI job codes have been introduced since the WIU last issued guidance. These can be used with MP&CE areas of work, to reflect the need for CBI STP training posts. The ESR system allows for accurate job splits so a staff member can be recorded twice using CBI and MP/CE codes with appropriate WTE. How about suggesting that at least two JDs in most small departments and some suitable percentage in larger ones have CBI as the primary specialism? To support CSC and WIU, Heads of Department should begin to consider how to use CBI in JDs.

Acknowledgements

We would like to acknowledge discussions with Dan Warren, who suggested the use of clustermaps, and also the other members of ICSIG who contributed to creating the survey questions. Finally, we thank the 125 respondents to the survey, and apologise for the delay in reporting results. The WIU really needs support from the membership when it requests information.

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A shorter version of this report was published as:

Chalkley et.al. 2021 *Patterns of Computing in MP&CE* IPEM Scope 31 (3) 46-49