The Creative Technologies Skills Gap

An analysis of the Emerging Creative Technologies Sector

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Table of Contents

Executive Summary

This report responds to the requirements of the UK's Institute of Coding initiative. Specifically, it aims to more effectively interrogate and map the requirements of the Creative Industries in relation to the discipline of Computing, including the identification of any current gaps in policy provision and how these might be bridged. By doing so, we attempt to further support and inform existing education, investment and policy initiatives that have capacity to strengthen the UK economy. As such, this report may be of use to those considering strategic development in areas of Computing and the Creative Industries, including in terms of education, and also in terms of research, innovation and investment.

In order to more fully understand the skills requirements for Creative Technologies, we present a mixed methods research study featuring semi-structured interviews with Creative Technology professionals from a range of Creative Economy fields, alongside data-driven research based on machine learning analysis of job adverts and online communities specifically representing Creative Economy workers. In particular, we focus on areas of the Creative Industries where Creative Technology is a core mechanism in content production and customer experience. We define Creative Technology solely with reference to its description in UK government data.[1] As such our analysis focusses on specific economic categories listed in the Creative Economy definition that fall within marketing, graphics, video, audio, games, architecture, design, journalism, and Information Technology (in creative industries contexts only).

The Creative Economy contributed close to £101 billion to the UK economy in 2017 (> 5% of GVA), and represents approximately 10% of all jobs in the UK. UNESCO reports that globally, the creative economy generated US$2.25 trillion in revenue in 2013 - substantially more than global telecommunications as a whole (US$1.57 trillion)[2]. A substantial number of Creative Economy jobs are in Creative Technology.

Our data shows a highly significant overlap between skills requirements that are traditionally considered as STEM only, and those required by Creative Economy workers. Further, our interview data helps define a profile for a specific kind of Creative Economy worker that is not currently well-reflected in either Standard Occupational Codes, or in academic research and teaching

[1] "Department for Culture, Media & Sport – Creative Industries Economic Estimates January 2015". gov.uk. 13 January 2015.
[2] UNESCO. 2015. Cultural times: The first global map of cultural and creative industries. (2015). http://www.unesco.org/new/fileadmin/MULTIMEDIA/ HQ/ERI/pdf/EY-Cultural-Times2015_Low-res.pdf

disciplines, but that nevertheless is indicated as desirable by our interviewees. These data support the position indicated by independent analysis informing the UK's industrial strategy, which we detail in depth in our discussion.

As a result, we are making two specific recommendations. First, we call for a wider range of interdisciplinary computing training programmes, such as Creative Computing degrees (BSc and MSc), technology conversion masters, postgraduate research programmes (MSc, MRes, PhD), and technology diplomas for the Creative Economy. Creative Computing is an emerging Computer Science discipline operating within Arts environments (such as the University of the Arts, Goldsmiths College, among others), and that has emerged over the last decade as part of the recognised need for stronger STEM skills in the Creative Industries. This recommendation is being made in order to meet the widely recognised supply issues relating to Creative Industry Digital Skills.

Secondly, in order to facilitate more efficient role analysis and hiring of appropriate staff across the sector, we recommend the establishment of new Standard Occupational Classification (SOC) codes as part of any upcoming refresh of employment standards (the last SOC update was carried out in 2010). **Specifically, we are calling for two new SOC codes: Creative Technologist, and Creative Programmer**. This is a crucial step in recognising the central role such employees have in the modern economy, and will help employers, academics, and policy makers better understand how the diversification of computing across the Creative Sector is impacting the working world. Further, it may help mitigate against current market failure in the recruitment of suitable staff across these and related industries.

Introduction

Creative Computing is a central component of the contemporary Creative Economy landscape. It underpins a significant proportion of the Creative Economy, with almost half of all Creative Economy jobs falling within the domain of Creative Computing. Creative Computing workers, sometimes referred to as "Creative Technologists", contribute significantly to the new digital economy, developing interactive devices, interfaces, software and services that drive laptops, smartphones, games systems and personal digital assistants.

However, some evidence suggests that both the scope and also the role of Creative Technologies is not well defined. For example, there exists no specific Standard Operational Classification (SOC) codes[3] - used to understand skills requirements for recruitment, immigration and many other purposes - for Creative Technologists. SOC Codes exist for games programmers, and general technologists, but not for those technologists working specifically in the creative industries more generally. There are SOC codes available to describe Web and multimedia *designers*, but no codes to describe the technical workforce that builds interactive web experience and multimedia systems through computing. One could argue that the requirements for creating websites, creative applications and multimedia systems are the same in the Creative Industries as for other general computing jobs. However, this assumption does not necessarily flow from the evidence. On the contrary there are reasons to believe that a general skills shortage in Creative Technologies is leading to an inability for the UK to deliver on its strategic priorities.

Recent research from Nesta[4] has shed some light on how Creative Technologies are defined. Following analysis of 41 million job adverts, the most in-need digital skills across a range of industries were in animation, multimedia production, design in engineering, networking, and quantitative data analysis / research. Despite the apparent crossover in skills requirements that can be seen in their data, Nesta's research tries to categorise creative jobs and STEM jobs separately. What it does not do is explore in detail how and in what ways STEM and creative jobs intersect in order to define the skills requirements of the Creative Technologies sector.

This is precisely what our report here attempts to achieve. We apply a mixture of qualitative and quantitative approaches, including semi-structured interviews, desk research and data-driven approaches in order to more effectively map the skills needs of industry in the Creative Computing domain.

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[3] https://www.ons.gov.uk/methodology/classificationsandstandards/standardoccupationalclassificationsoc

[4] https://www.nesta.org.uk/report/which-digital-skills-do-you-really-need/#content

In this way, we are the first attempt to define Creative Technologies in a manner that is meaningful for industry, academia and policy makers, and that will help to establish a greater level of consistency in the UKs approach to Creative Computing.

Aims and Objectives of research

Aims

- Define Creative Technologies through a range of data-driven, desk-based and interview-based research methods.
- Define skills requirements for the Creative Technologies sector based on industry needs and statistical analysis of online data.
- Identify future opportunities for skills provision.

Objectives

- Create a means to better understand Creative Technologies, including its future potential as an economic driver within the Creative Economy.
- Create a strong rationale for further establishing Creative Computing as an academic discipline that can fulfil the requirements of the Creative Technologies sector.
- Suggest ways forward to strengthen the sector in terms of skills provision and supply in the future.

Background

Defining Creative Technologies

Creative Technologies includes any technology that is involved in the process of creating, consuming, analysing or discussing creative experiences. Technology areas relevant to the Creative Industries therefore include any and all aspects of technology relating to sound, image, video, fashion, devices, environments (e.g. architecture), interaction (including both games and devices), presentation (and representation), analysis (including metrics) and discussion (including online).. Computing fields relating to these by extension include sound and signal processing, image processing, content analysis, feature extraction, media information retrieval, recommendation and personalisation, machine learning / AI, parametric architecture, computer graphics, sound synthesis, simulation and human-computer interaction.

Some may argue that these areas of computing are not of real interest to those working in the Creative Industries. However, evidence from national statistics, non-government organisations, and the Creative Industries themselves suggests otherwise.

The Department for Digital, Culture, Media and Sport's (DCMS) 'Culture is Digital' report cites £2.45 billion of private investment in the London-based technology sector in 2017[5]. However, the DCMS report also indicates the sector lacks necessary expertise in data analysis, AI and other areas where there is considerable potential for growth. The creative digital skills gap in the UK is considered greater than anywhere else in Europe, projected to lead to 250,000 vacant digital jobs by 2020. London's Silicon Roundabout outperforms the rest of the UK in jobs growth in the digital sector. The Industrial Strategy has a major challenge focus on AI and Big Data, including an AI sector deal of almost £1 billion. Some of this investment is being made squarely within the Creative Economy, but the extent to which this is happening is not well understood.

According to UK ONS data[6], the engineering sector is a huge part of the UK economy, representing just under 1 in 5 of all UK jobs (18.9%). Engineering incorporates a number of areas critical to UK productivity, the biggest of which are manufacturing (42.3%) and Information & Communication (19.5%). Both of these intersect significantly with the Creative Technologies in areas of design, customisation, information retrieval and machine learning. The manufacturing sector represents 11% of UK Gross Value Added (GVA), and approximately 8% of all jobs (2.6 million). The creative economy contributed over £101 billion to the UK economy in 2017, £90 billion in 2016 (5% of GVA), yet represents 10% of all jobs. Approximately half of these jobs are in Creative Technology fields. The creative economy has grown more than three times faster than any other UK sector over the last five years, and twice as fast as the UK economy as a whole, although this growth is mainly concentrated in London.

Skills and knowledge development in Creative Technology directly benefits UK industry more broadly. Creative Economy workers in manufacturing include front-end website developers, interaction designers and product developers. The emergence of personalised and AI-enhanced user experiences are areas projected to make significant economic contributions in the coming decade, and a great deal of this work will be carried out by Creative Technologists. Some projections indicate economic benefits across the UK of over 8.4% of GDP in

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https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/686725/Culture_is_Digital_Executive_summary__1_.pdf

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the next 10 years (Asgard 2017[7]) from personalisation technology alone.

Issues surrounding the intersection of STEM and Creative skills have been acknowledged many times. In 2013, Davis & Ward Dyer[8] noted that the UK was experiencing ‘an alarming mismatch between the supply and demand for creative skills, with severe skills shortages precisely in the Internet–related areas where UK businesses need to compete.’ (96: 2013). That 2013 report is unequivocal as to the consequences of these ‘severe skills shortages and gaps’ (97: 2013); ‘digitisation has exposed creative, technical and management–related skills deficiencies in the UK’s creative workforce that demand urgent attention if its creative businesses are in the future to succeed in Internet markets.’ (97: 2013). Another report by the UK Commission for Employment and Skills, published in 2015, cited the lack of workers with digital skills as presenting the sector’s ‘greatest recruitment challenges’[9] (7: 2015). That report also made a case for creative technology, stating that it would be a mistake to make too clear a distinction between technological knowledge and its creative application: ‘The boundaries between digital and creative are becoming increasingly blurred and employers increasingly seek a fusion of creative and technical skills, combined with business and softer skills.’[10] (7: 2015). A 2016 report by Brighton *et al* also noted the lack of appropriate skills, especially in digital fields, as one reason for the relative lack of productivity in the UK’s creative sector: ‘The big challenge for the creative sector will be finding people with the digital skills and understanding to ensure that the sector’s firms remain productive.’ [11] (53: 2016).

A more recent report from the European Parliamentary Research Service[12], points out that technological change is affecting artistic activity (for instance by making possible new kinds of creative community and forms of creation, through the use of algorithms in the creative process and through changes in hardware) as much as artistic activity is affecting technology (stimulating developments in hardware, influencing the development of AI and through creatives developing their own artistic tools). The European Parliamentary Research Service report suggests that, in response to automation, we can expect greater incentives for companies to invest in the combination of artistic

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[7] https://asgard.vc/research/
[8] NESTA. 2013. A Manifesto for the Creative Economy.
[9] UK Commission for Employment and Skills. 2015. Sector Insights: Skills and Performance Challenges in the Digital and Creative Sector: Executive Summary
[10] UK Commission for Employment and Skills. 2015. Sector Insights: Skills and Performance Challenges in the Digital and Creative Sector.
[11] Robin Brighton, Chris Gibbon, Sarah Brown and Aoife Ni Luanaigh. 2016. Understanding the Future of Productivity in the Creative Industries: Strategic Labour Market Intelligence Report. Institute for Employment Studies / SQW
[12] John Davis and Georgia Ward Dyer. 2019. The Relationship between Artistic Activities and Digital Technology Development. European Parliamentary Research Service.

and technological skills. We can also anticipate, the report suggests, a growth in immersive technology platforms that create demand for artistic skills. Finally, we can expect greater integration of digital, design and data skills as a result of the internet of things. In the future, then, demand for the combination of artistic and technological skills is only likely to increase, with a growth in demand for 'products and services that combine technological sophistication and high levels of design in aesthetic or user experience terms, in turn raising the demand for the integration of technological and artistic skills'[13] (Executive Summary, II, 2019). As the Creative Industries Council has pointed out, creative technology - or 'createch' - is already 'a fast-moving and hugely dynamic part of the UK economy', a 'catalyst of innovation, providing solutions and improving experiences'.[14] As the Creative Industries Council state, however, the country has the potential to go even further, to become the global leader in createch as it already is in financial technology or 'fintech'.

The World Economic Forum[15] has called attention to a growing 'skills instability' resulting from the sheer pace of technological change, creating a need for employees able to learn new skills rather than simply rely on existing knowledge. This resonates with a 2017 report by Bakhansi *et al* that states that 'the future workforce will need broad-based knowledge in addition to the more specialised features that will be needed for specific occupations.[16]

Methodology

We deployed a mixed-methods approach featuring semi-structured interviews, conducted both in-person and online, and data-driven methods, specifically natural language processing in combination with machine learning-based clustering. The former methods were intended to build a more complete picture of the Creative Computing needs of a selection of industry experts, all of whom work in key roles within the Creative Economy. The latter, data-driven approach was targeted at understanding two specific things. First, how Creative Economy employers were advertising for key roles in their organisations, and secondly, the kinds of problems that Creative Technologists often faced. In the second case, we hypothesized that through exploring online communities such as stack overflow, we might be able to further explore the issues surfacing as part of Nesta's 2018 report.

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[13] John Davis and Georgia Ward Dyer. 2019. The Relationship between Artistic Activities and Digital Technology Development. European Parliamentary Research Service.

[14] Creative Industries Council. 2019. Createch: Ones to Watch.

[15] World Economic Forum. 2018. The Future of Jobs Report.

[16] Hasan Bakhshi, Jonathan Downing, Michael Osborne and Philippe Schneider. 2017. The Future of SKills: Employment in 2030. Pearson / Nesta

Semi-Structured Interviews.

In order to understand how industry might perceive potential gaps in skills in the field of creative technologies, we contacted professional creative technologists, creative technology team leaders, and consulting organisations in order to engender open discussion. We decided that in order to allow respondents to be as frank as possible, all responses would be anonymous. No personal information about the interviews was collected or shared, including information that might possibly identify any contributing professional staff. We had an high quality responses from ten contributors including from the audio and music technology industry (Artificial Intelligence Start-ups in the domain of music), creative technologies product developers (including those developing new interfaces using machine learning, 'big-tech' companies (specifically Google), broadcast professionals (BBC, Channel 4), games developers, digital marketing specialists, digital designers, and architects. Not all questions were appropriate for all partners and some deviation did occur in order to keep the tone of the interviews rational and appropriate. Just over 80% of the interviews included in-depth, in-person conversations regarding the type and manner of course provision that respondents would like to see, which was helpful in preparing recommendations. The Interview Questions can be viewed in appendix 1.

Quantitative Data Methods

Datasets

To explore the requirements of the Creative Technology industry we used two publicly available documents from two specific domains. Taking a similar approach to that which has been adopted by other researchers, including Nesta in their 2018 report, we first analysed a large selection of job adverts posted on UK based portals to attempt to evaluate the demand for job applicants in the Creative Economy. Results from these job portals included those from *Monster.co.uk*, *Reed.co.uk* and *Indeed.com*. Secondly we analysed documents on the question and answer portal *Stack Overflow,* specifically on seven different stack overflow sites which serve as specific community discussion forums for a mixture of Creative and Digital Economy professionals. As such these data sources can highlight the technologies that are actively used by these communities based on the questions that they ask.

In order to narrow and refine search results for these datasets, we chose to define Creative Technology solely with reference to its description in the

DCMS's own data.[17] In this way, we represented the sector based on nine specific economic categories that include IT, marketing, video, audio, architecture and other creative economy fields. We then used these categories to select keywords to search over the selected portals.

While the data of Stack Overflow is available through regularly updated public databases, the selected job portals do not provide a publicly accessible Application Programming Interface (API). We used the software *Octoparse* to assemble the advert document dataset.

Job portal	Documents
Monster.co.uk	2874
Reed.co.uk	2915
Indeed.com	5150

Table 1:Number of documents gathered from job portals for the purposes of analyzing job requirements in the Creative Sector relating to Creative Technologies

Stack Overflow site	Documents (Q)
Game Development	46k
Graphic Design	28k
Data Science	18k
Signal Processing	17k
Artificial Intelligence	4.3k
Computer Graphics	2.4k
Internet of Things	1.4k

Table 2. Topics and number of questions gathered from the Stack Overflow community sites relating to specific Creative Industries fields.

The resulting datasets consist of 10.9k job ad documents and 117.1k randomly selected questions from seven *Stack Overflow* sites as described by Tables 1

[17] "Department for Culture, Media & Sport – Creative Industries Economic Estimates January 2015". gov.uk. 13 January 2015.

and 2. In the case of the *Stack Overflow* question data, we chose to normalise the number of documents for each of these communities, selecting a random subset of 2250 documents (only 1400 in the case of “Internet of Things”). We further selected a uniformly sampled subset of 13k documents from the *Stack Overflow* data as a representative sample for analysis.

Data pre-processing

As a part of the data collection process we included several pre-processing steps to clean the scraped dataset of unwanted features (such as remaining html tags etc.). We then prepared it for language modelling analysis. This process included removing generic words, and also stop words which are frequent in natural language. This is because although they are common, they do not add any relevant information about the topic (stop words included, for example: “a”, “this”, “so” etc.). Following this, we lemmatised and tokenised the documents in both datasets in order to reduce the dataset to individual terms. We used bigram and trigram models to connect related single tokens together (For example, “central” and “London” were converted into a single and more descriptive token “central_london”). Finally we arrive at a dataset which contains lists of documents represented by lists of tokenized words.

Analysis

To analyse each dataset we used a standard language modelling method known as Latent Dirichlet Allocation (LDA)[18]. This method assumes *k* underlying topics present in all the documents in the dataset (with the value of *k* being decided by the researcher). To select the parametric value of the number of topics in the model, we empirically evaluated all sensible values within a reasonable range and compared the resulting perplexity and coherence scores, as is standard when using LDA. We used the Gensim python library[19] in order to carry out this analysis.

[18] Blei, David M., Andrew Y. Ng, and Michael I. Jordan. "Latent dirichlet allocation." Journal of machine Learning research 3, no. Jan (2003): 993-1022.
[19] Rehurek, Radim, and Petr Sojka. "Software framework for topic modelling with large corpora." In Proceedings of the LREC 2010 Workshop on New Challenges for NLP Frameworks. 2010.

Results

Data Analysis

Below, we visualize the topics derived by our LDA model using word clouds. We also annotate each document by its dominant topics. Further, we create a histogram of the document topic distribution across the dataset. The job advert dataset is shown in Figure 1 and the Stack Overflow dataset in Figure 2. Note that the histograms don't include contributions of any other than the dominant topics.

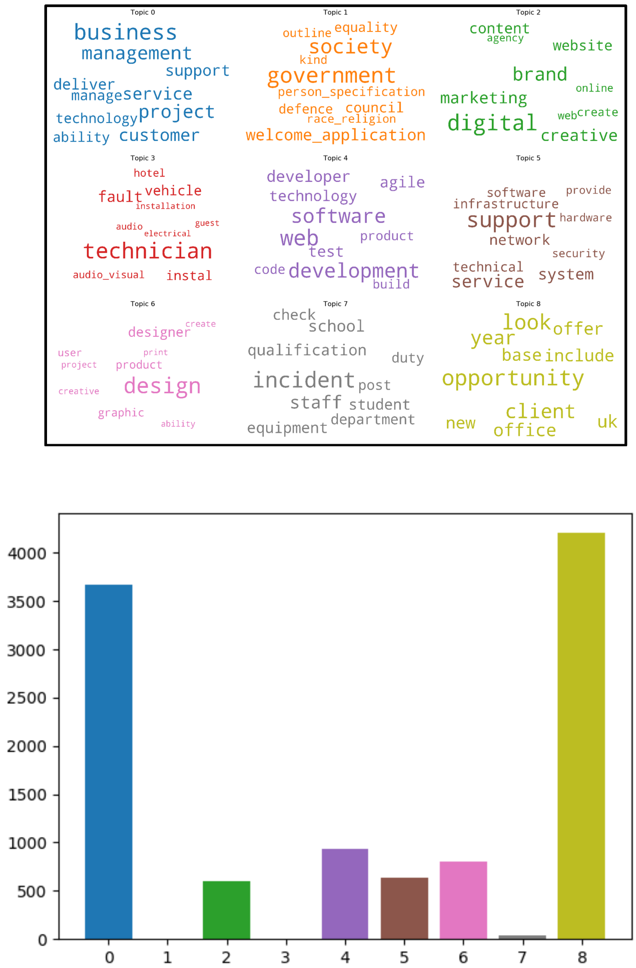

Figure 1: Nine topics of the job ads dataset as visualized by wordclouds and a histogram of dominant topics. The colours selected for each topic in a dataset are fixed across other figures. Note that only the first topic is taken into consideration and as such some of the more generic topics do not have any documents associated with them - see for example Topics 1 and 3. On the other hand Topics 0 and 8 seem to be dominating the entire dataset. If we examine the keywords of Topic 8, we can see that they are generic words which would be present in many ad postings (such as the words "opportunity"). Note that each topic is defined by the algorithm, and is interpreted by its content specifically through further analysis.

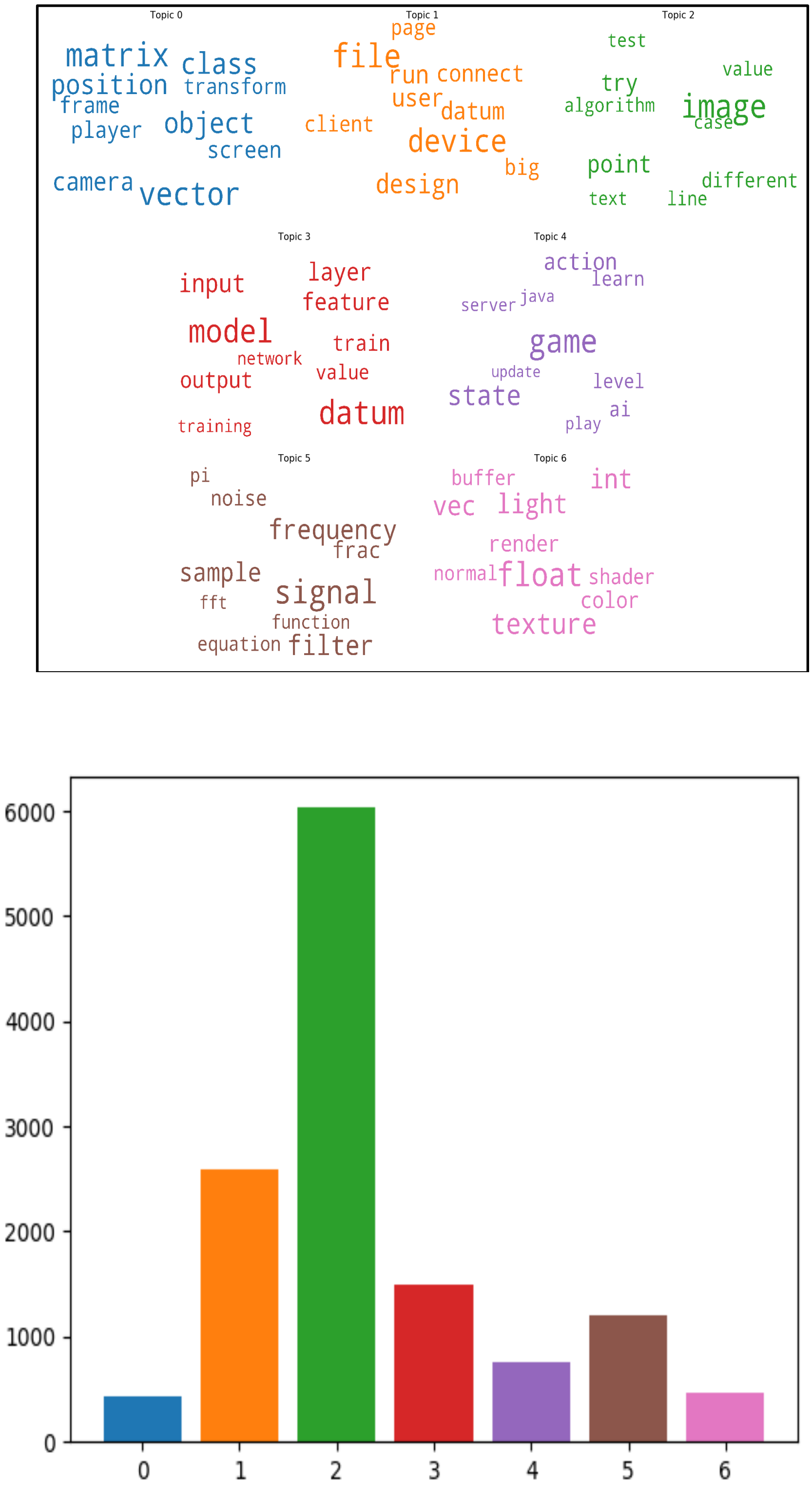

***Figure 2**: Seven topics of the Stack Overflow dataset as visualized by wordclouds and a histogram of dominant topics. The colours selected for each topic in a dataset are fixed across other figures. Note that Topic 2 dominates the dataset while including both generic keywords such as "algorithm" or "try".*

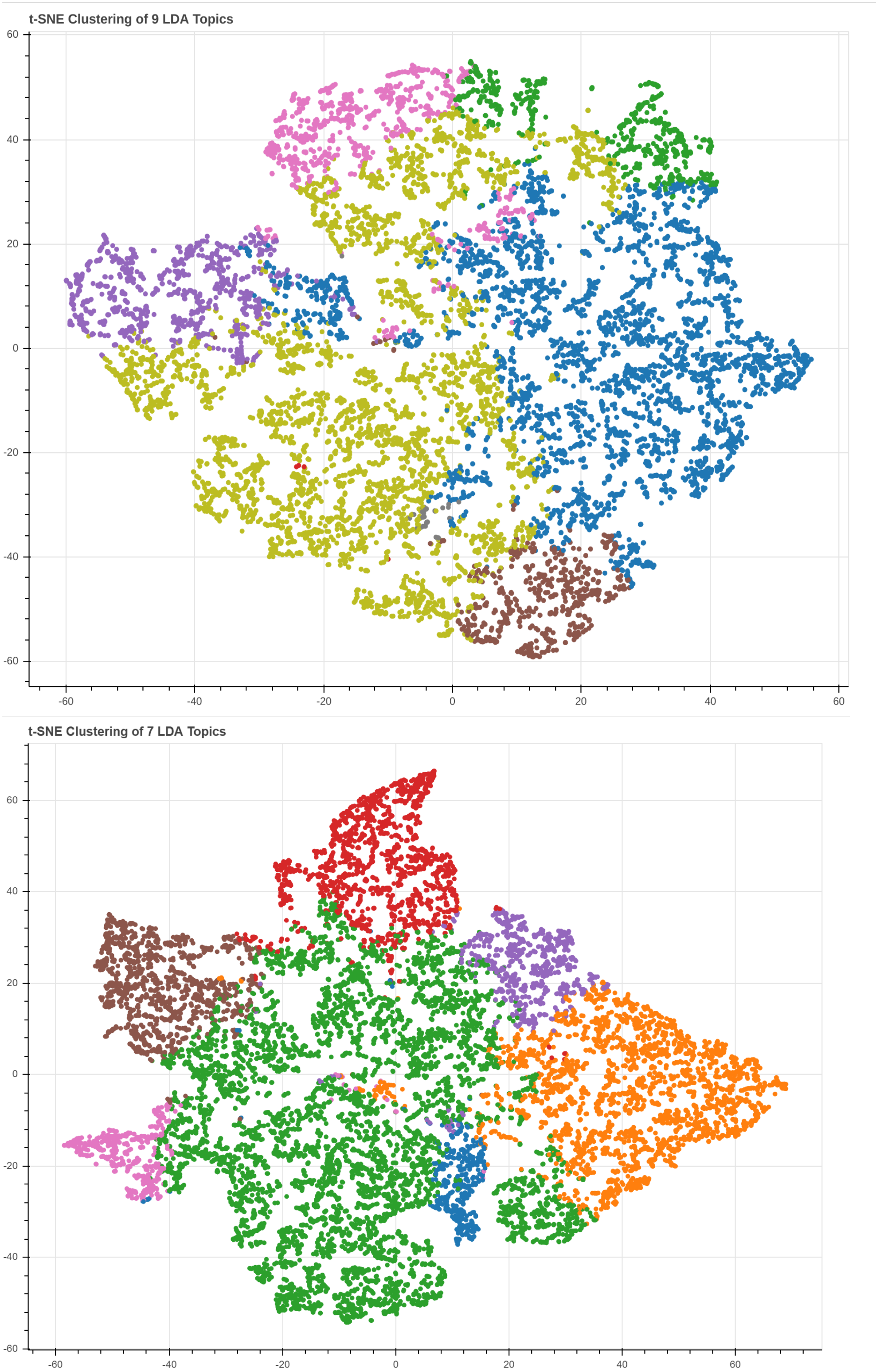

Figure 3: T-SNE visualization of the model's embedding of all the documents across the dataset. We can see separability of topics and dominance of one topic over others. These interactive plots with descriptions of the question titles are also available at https://ual-cci.github.io/Reports/2019_09_IoC/job_ad_analysis/tsne_9.html and https://ual-cci.github.io/Reports/2019_09_IoC/qna_stackoverflow_analysis/tsne_7.html.

Using the transformation of the LDA model's projection we can represent each document as a vector of its contributions to the selected number of topics. These features are visualised by the T-SNE method[20] in figures 3 and 4. All documents in the dataset are coloured by classification by their dominant topic. Latent topic representations presented by their keywords can be seen as data derived labels and can be further interpreted by expert domain knowledge.

In Figure 4 we further visualise the data from the Stack Overflow dataset by their correspondence to the seven selected communities. While the embedding space of the model and its T-SNE visualisation keeps the individual documents in the same data-derived clusters of topics, we can also see how spread apart the individual categories are. Questions asked within one community often spread across multiple topics present in the whole dataset. This clearly indicates significant cross fertilisation across the topics, despite them crossing traditional STEM / Arts boundaries. Finally, we also present an interactive visualisation of the topics using the pyLDAviz python library[21] in Figure 5.

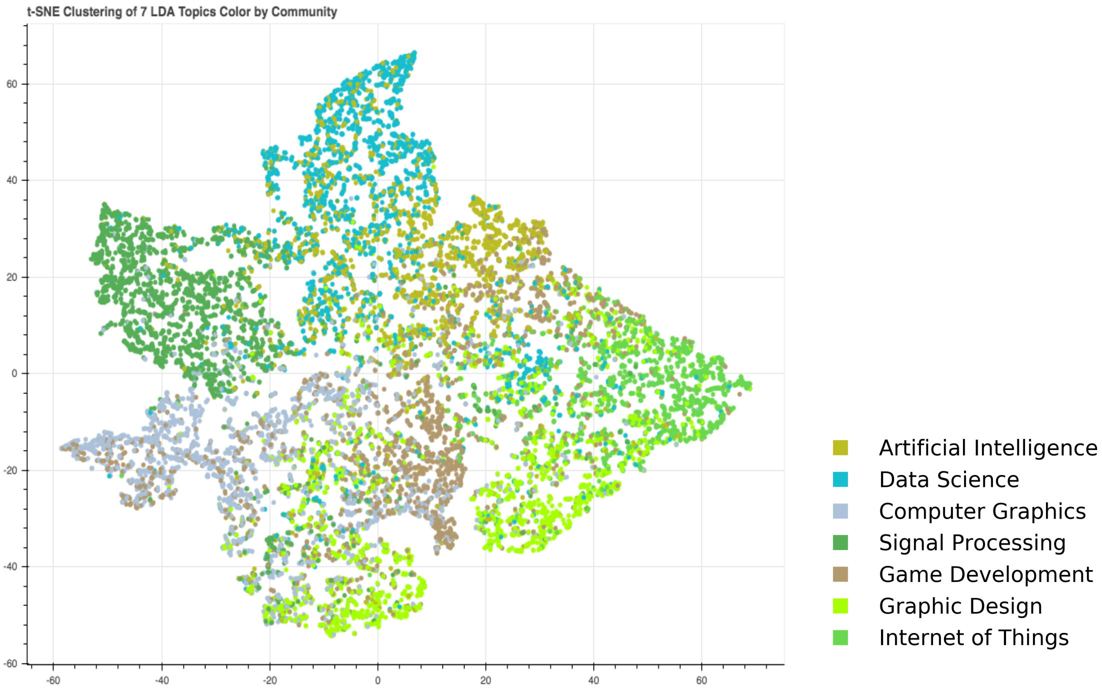

Figure 4: Stack Overflow dataset as visualized with same T-SNE embedding and colours derived by the community each document belongs to. Interactive visualization of the embedding is available at https://ual-cci.github.io/Reports/2019_09_IoC/qna_stackoverflow_analysis/tsne_7__colorByCommunity.html.

[20] Maaten, Laurens van der, and Geoffrey Hinton. "Visualizing data using t-SNE." Journal of machine learning research 9.Nov (2008): 2579-2605.
[21] Sievert, C. and Shirley, K. (2014): LDAvis: A Method for Visualizing and Interpreting Topics, ACL Workshop on Interactive Language Learning, Visualization, and Interfaces.

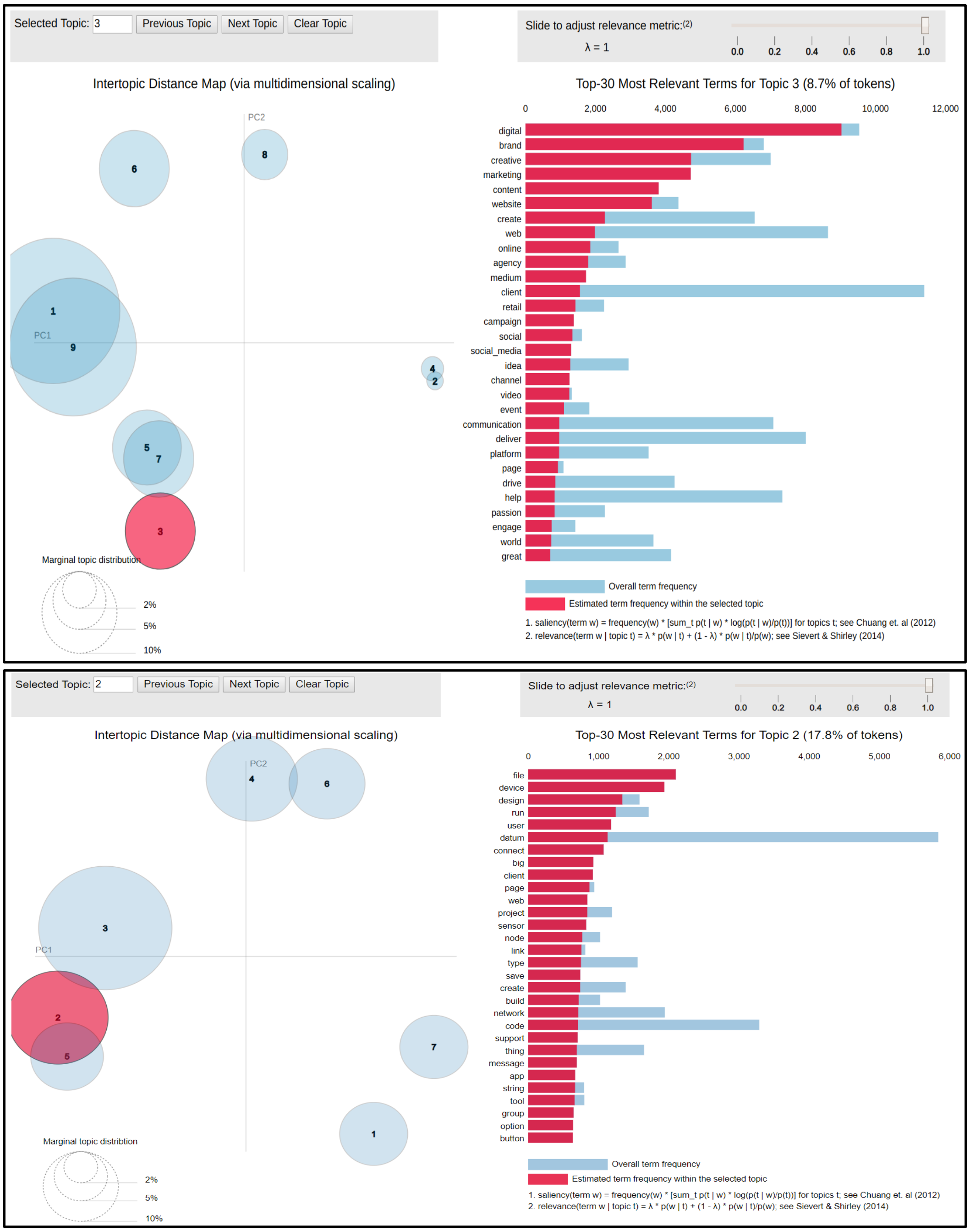

Figure 5: *Interactive visualization of LDA topics using the pyLDAviz library. Note that the indexing made by this library starts the topics from number 1, while in the rest of the figures it starts with 0. However, the order of topics is the same. These documents are available for inspection online* [22], [23].

Summary of Quantitative Observations

Some potentially interesting and relevant observations can be made when inspecting the above. In Figure 1, by far the most common job advertisement topics appear to relate to technology project management, marketing and

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[22] https://ual-cci.github.io/Reports/2019_09_IoC/job_ad_analysis/LDA_Visualization_9topics.html

[23] https://ual-cci.github.io/Reports/2019_09_IoC/qna_stackoverflow_analysis/LDA_Visualization_7topics.html

sales. The most common topic (topic 8) contains the keywords “client, opportunity, look, offer”, and the second most common topic (topic 0) contains “business, project, services, customer” (in order of weight). This strongly reflects the core commercial context represented by the dataset. However, the third and fourth largest topics (topics 4 and 6) contain purely software engineering and design-related keywords (“web, software, development, agile, test” and “design, designer, graphic, product, creative”). These two are closely followed by topics 5 and 2, that focus purely on technology infrastructure (“support, service, system, technical, infrastructure”) and web design (“digital, brand, creative, marketing, website”). Looking more closely at the data, after core commercial sales and marketing requirements, the most prominent keywords in all topics in size order are “web, software, development, design, digital” and “brand”. This makes clear that the current job market across the creative industries is strongly focussed on hiring web programmers in the context of design and branding.

Figure 2 comprises topic graphs and wordclouds that characterise the Stack Overflow datasets relating specifically to questions relevant to Creative Industries outcomes, and that have been asked across a range of targeted communities (see Table 2 above). What this figure indicates most strongly is that creative industries-related work captured in these data may consist of highly contextualised intersections between creative and technical roles. Topic 2 is the largest topic by far and contains the following keywords (in order of weight): “image, point, try, value, line, algorithm”. This reveals a clear intersection between what is often considered solely technical (value, algorithm), and that which is solely creative (image, point, line). This might come as no surprise to those involved in the modern creative industries, and it is potentially significant that this topic is well over twice the size of the next nearest topic in the data. The second largest topic in Figure 2 (topic 1) reinforces this observation, consisting of (in order); “file, device, design, run, user”. This appears to represent a clear intersection of design and technical content, similar to that which you might commonly find in interdisciplinary Human Computer Interaction (HCI) and product design. The next two topics (3 and 5) are clearly machine learning (“model, datum, layer, input, train”) and signal processing (“signal, filter, frequency, sample”), the former being essential to many new fields including creative technologies, the latter being representative of the requirements of music technology workers. Finally, the smaller topics in this set appear to represent specific games programming issues (“game, state, action, level, play”), and computer graphics / shader processing (“float, texture, light, vec, render”) in more or less that order.

What this may indicate is an overemphasis on the perceived importance of computer games in terms of creative technology skills. SOC codes for “computer games developer” have existed for almost ten years, and games is well enough established in terms of training provision. However, given that the data source for games documents was far larger (20 times that of the computer graphics sample), it is even more notable that the technical need, as expressed by the topics of the questions themselves, appears mainly to be in image, data and sound processing, in a way that is substantially greater than the need for expertise in core games technology.

The T-SNE cluster-plots in figure 3 show the documents with reference to their most prominent topic. In the job adverts dataset, it is clear as one would expect that sales and marketing dominate, and intersect one another, meeting in the centre. Interestingly topic 6 from this group (design) is bisected by marketing, and intermingled somewhat with management. However, the remaining topics (digital branding, software development, support services) appear reasonably distinct, and the same can be said with respect to the Stack Overflow dataset.

However, it is possible that some topics are more spread out than others, and we attempt to address this in Figure 4 through further clustering analysis of the Stack Overflow dataset based on the *community which each document belonged to*. As already mentioned, this figure shows that there is significant cross fertilisation across traditional STEM/Arts boundaries in each of these communities. Far from being clearly delineated against the extracted topics, there are some communities where a number of topics are under discussion. We have ranked these in Figure 4. In particular, Artificial Intelligence and data science appear highly dispersed and intermingled across the range of topics. This is not immediately obvious from looking at the topics themselves, and suggests a need for further research. What is clear is that it seems AI and data science is having a strong impact on Creative Industries skills requirements generally, and as such there may be a need for training in data science and AI for the Creative Industries.

Figure 5 shows interactive plots of the LDA topics extracted from the dataset, hosted by the Creative Computing Institute (CCI). This allows the reader to further interrogate the data sets and outcomes. These can be found below:

https://ual-cci.github.io/Reports/2019_09_IoC/job_ad_analysis/LDA_Visualization_9topics.html

https://ual-cci.github.io/Reports/2019_09_IoC/qna_stackoverflow_analysis/LDA_Visualization_7topics.html

Interviews

Workers in the creative industries[24] generate significant value: the fact that these industries now contribute over £100 billion to the UK economy[25] has been widely reported. What is less widely reported, however, is the very significant overlap between the creative industries and what is classified by the DCMS as the 'digital sector' - and the huge demand for employees who exist at precisely this interface between creativity and technology. Emerging clearly from the interview data is the fact that employers face significant difficulties in recruiting creative technologists, particularly at senior levels. While theoretical computing knowledge is considered helpful by those interviewed, it is practical knowledge of programming that they consider vital. Asked to use a Likert scale from 1 (not important) to 5 (very important), respondents unanimously awarded knowledge of basic programming languages a 5. Theoretical computing knowledge, meanwhile, typically scored 3 – and in some cases only 2. Python, JavaScript and C++ emerge as the most sought-after languages, while there appears to be an urgent need, too, for knowledge of machine learning, human computer interaction and signal processing skills.

There was also agreement among respondents that creative technologists do not require advanced programming skills, which respondents typically awarded a 3 on a Likert scale stretching from 1 to 5. While 'hard' programming skills are desirable to employers, they are not as urgently required as the ability to imaginatively and appropriately deploy those skills. Employers want to recruit people who are flexible and curious, able to acquire new skills and to explore new ideas, rather than those with a single narrow area of expertise. Asked about the most important skills for creative technologists, one respondent replied as follows:

> Imagination and self-direction: 'hard' programming skills are fantastic, but the best CTs I've worked with originate their own ideas and use their hard skills to achieve them. 'Creative' should drive the use of 'Technology'.

In response to a follow-up question about the most valuable skills for new employees, he replied in a similar vein:

> Versatility, and curiosity around learning new skills, is more useful than a single area of extreme expertise; great creative technologists can hack

[24] We refer in this report to both the creative industries (usually understood to refer to specific sectors, for instance advertising and marketing; architecture, crafts; product design, graphic design and fashion design; film, TV and radio and photography; IT, software and computer services; publishing; museums, galleries and libraries; and music, performing arts and visual arts) and to the broader creative economy (which takes into account spillover effects and contributions to other sectors).

[25] DCMS Sectors Economic Estimates 2017: GVA. 2018. https://www.gov.uk/government/statistics/dcms-sectors-economic-estimates-2017-gva

> with a machine learning API application programming interface in the morning and solder together a prototype after lunch.

Other comments made by respondents were along similar lines. One interviewee commented:

> Very specialist skills (e.g. research and production-quality code) are fantastic, but a Creative Tech[nologist] should be above average at many things rather than specialist in one or two.

A third interview respondent stated that he aimed to hire polymaths as creative technologists, explaining:

> Specialists are great for niche projects but often struggle outside their domain.

Discussion

The outcomes of the qualitative interviews largely align with the outcomes from our quantitative analysis. There is a significant intersection between what are traditionally thought of as STEM skills, and skills requirements of the Creative Industries. In particular, there is a recognised skills gap, already identified by government and industry, that is not currently being filled by education providers – with the possible exception of games, which at least, according to our data, did not register as a domain with a significant skills gap compared to other domains.

Current and Emerging Skills Gaps

Our data and interview process indicates strongly that creative industry fields including marketing, graphics, imaging, audio / music, architecture and product design are highly dependent on core programming expertise in web programming, graphics and imaging, signal processing, data science, AI / Machine Learning, and Human Computer Interaction, in particular from those with a strong understanding of creative industry content, management, sales, branding and project development. Our interviewees unanimously privileged practical programming expertise in these domains, as opposed to specialised and or theoretical knowledge in any one specific computing area.

This appears somewhat antithetical to how computer science education has traditionally been delivered i.e. in theoretical and / or abstract contexts rather than in domain specific contexts, and in relation to mathematics as a discipline rather than the disciplines where the knowledge and skills will be applied. This may explain why there is a recognised gap, and low employment amongst computer science graduates. What it also reveals is that notions of a natural separation between 'STEM' and 'The Arts' are misconceived and not beneficial to industry, and that above all, interdisciplinarians with the knowledge and skills to understand and work around this problem are in high demand.

Creative technologists make up approximately half of creative economy jobs and represent almost half its economic value.[26] And yet the importance of creative technologies is easily underestimated - particularly, perhaps, within academia, since faculties and departments struggle to accommodate the subject's inherent interdisciplinarity. This, perhaps, helps to explain the striking gap in creative technology skills among graduates. To address this gap will require significant changes within higher education. Yet the urgency of need also represents a clear opportunity for higher education institutions: to introduce courses which not only exist at the intersection of creativity and computational technologies but which understand those two components as of equal importance. Crucial to these creative computing courses should be a close - and mutually beneficial - relationship with industry. This does not mean that universities should adopt a passive, 'skills pipeline' role of simply preparing students for jobs that already exist. Instead, it means a curriculum informed by industry needs, as computer science courses, for instance, are not: at present, 'high vacancy rates for digital roles coexist with high rates of unemployment amongst computer science graduates'.[27] Yet it also means that universities should drive change within the creative industries, introducing new models and ways of working. And it means a much closer relationship between research and knowledge exchange, and new opportunities for instance in collaborative R&D.

For employers, such courses will help to fill the obvious skills gap; for students, they will provide greater employability than more theoretical courses in computer science. A greater emphasis on creative computing will also unlock economic value: overwhelming in the interview data is a view of coding as critical to the future of the creative industries and, as outlined above, this view is also echoed in the literature. Society will benefit too from a tech workforce that has a greater understanding of the social and ethical issues more often associated with arts and humanities subjects than with computer science. In a world that is defined through human-computer interaction and social platforms, there is an urgent need to create socially responsible graduates that combine technical knowledge with reflexivity and critical thinking.

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[26] Mick Grierson. 2017. Goldsmiths Digital: Research and Innovation in the Creative Economy. In: Morag Shiach and Tarek Virani, eds. *Cultural Policy, Innovation and the Creative Economy: Creative Collaborations in Arts and Humanities Research.* Palgrave, pp. 83-95. ISBN 978-1-349-95112-3

[27] UK Commission for Employment and Skills. 2015. Sector Insights: Skills and Performance Challenges in the Digital and Creative Sector.

The need for courses teaching something akin to creative computing has been increasingly acknowledged in recent years. In recognition of the 'central' importance of employees able to combine artistic and technical skills, one recent report has called for the education system to provide 'greater opportunities to study artistic and science/engineering subjects in parallel', with the aim of promoting 'the cross-pollination of skills and ideas between fields'.[28] That report cites the example of fine arts undergraduates, who, it is argued, 'should have the opportunity to learn programming and study core maths courses, such as calculus and linear algebra.'[29] This recommendation echoes a report by the Creative Industries Council, which states that 'young people should be able to study a fusion or combination of creative, technical, scientific and entrepreneurial subjects' through an education system that promotes STEAM (Science, Technology, Engineering, Arts, Maths) and not just STEM.[30] A similar case is made by a 2013 Nesta report[31], which states that 'all teenagers should have the opportunity to learn creative digital skills, such as designing apps and games, as part of a fusion in the curriculum covering technology and art, as well as maths, science and the humanities.' Indeed, the UK Government itself has acknowledged the need for creative computing: Matt Hancock, at the time Secretary of State for Digital, Culture, Media and Sport, stated in a 2018 report that 'the UK's future will be built at the nexus of our artistic and cultural creativity and our technical brilliance.'[32] And yet that report also sounds a note of warning: 'The UK technology and cultural sectors make the ultimate power couple but more action is needed to make sure that they share the same interests.'[33]

Creative Computing as a discipline is well placed to address this issue. BSc and MSc Creative Computing courses offer highly contextualised computer science provision that focusses on domain-relevant programming, algorithms design and project delivery expertise. Goldsmiths College were the first to construct such a degree programme, and it has been highly successful, with high numbers of employed graduates, and a significantly reduced gender gap. Creative Computing undergraduate and postgraduate degrees are now in place at the University of the Arts, Queen Mary University of London, Falmouth and Bath Spa.

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[28] John Davis and Georgia Ward Dyer. 2019. The Relationship between Artistic Activities and Digital Technology Development. European Parliamentary Research Service.
[29] John Davis and Georgia Ward Dyer. 2019. The Relationship between Artistic Activities and Digital Technology Development. European Parliamentary Research Service.
[30] Creative Industries Council. 2014. Creative Industries Strategy.
[31] NESTA. 2013. A Manifesto for the Creative Economy.
[32] DCMS. 2018. Culture is Digital: Executive Summary.
[33] DCMS. 2018. Culture is Digital: Executive Summary.

It is clear from our data that more such courses are required. The industry interviewees, themselves all leading creative technologists, are united: there are significant challenges in finding employees with the required mix of creative and technological skills. Despite talk of bridging the arts and sciences, and of STEAM rather than STEM, we still tend to think of creative industries workers as emerging from traditional arts and humanities backgrounds – engaged with digital technologies, perhaps, but probably not able to code. Striking in both the qualitative and quantitative data analysed for this report is the sense that such a picture is no longer accurate: there is an increasingly urgent need, within the creative industries, for workers with knowledge of computing. As employers, however, the interviewees do not seek computer science graduates with highly specialised knowledge. Instead, they are looking for employees who have a broad understanding of technology but who also understand the creative industries context in which they might be employed.

This is of vital importance to the future of the UK creative industries. Sir Peter Bazalgette puts it in black and white, stating that these industries are of 'central' importance to the UK's productivity and global success - but also that maximising this potential will require 'blended technical and creative skills' as well as collaborative interdisciplinary working, entrepreneurialism and enterprise.[34] As he states:

> The digital era… represents an enormously exciting opportunity for a further wave of growth and innovation. But we will need to work hard to harness the value of the IP [intellectual property] in these sectors and invest in R&D [research and development] to secure our reputation as the most innovative place to make creative content. We need to exploit technologies … to keep innovation strong. We need to reimagine this as a 'creative-tech' sector. The value that they bring is not only to the creative industries themselves but also as enablers to the wider economy.[35]

Conclusion and Recommendations

Opportunities for Skills Provision

We propose that computing courses should be made more relevant to specific industry needs, being more solidly designed towards specific application domains including marketing, graphics, imaging, audio, architecture and product design, favouring practical programming experience with sounds, images, devices and interactions, rather than towards abstract computational

[34] Peter Bazalgette. 2017. Independent Review of the Creative Industries.
[35] Peter Bazalgette. 2017. Independent Review of the Creative Industries.

approaches, as is the case with many computer science undergraduate degrees. This is not to say that the study of abstract computational approaches is not critical to developing a strong understanding of computing, nor that it should not feature in contemporary creative computing whatsoever, simply that it should perhaps not dominate in the way it has in the past – at least not in all cases, specifically when it is clear from our data that there is a great intersection between a range of domains and disciplines, and computing as a subject. If programmes can be designed in ways that reflect the broader needs of industry with respect to computing skills in the wider world, they can bring more value, both to the employer in terms of provision, and, perhaps more importantly, to the student.

Good examples of this practice, and which have established a strong HE presence include the work of Goldsmiths Department of Computing, and the University of the Arts London's Creative Computing Institute. BSc and MSc programmes in Creative Computing should deliver core programming expertise.This should be in sound, image, video, interactive contexts, incorporating targeted training in computer graphics, image and signal processing, applied linear algebra for machine learning, embedded systems, HCI, project development and professional practice. Our data demonstrates that there is not currently as great a skills gap in games, as this field is fairly well established.

Our research indicates that there is a very strong intersection across a range of Creative Economy work. Specifically, the T-SNE plot in Figure 4 clearly demonstrates how work considered to exist solely in the domain of the arts, such as graphic design, strongly intersects with what has been traditionally seen as being relevant to STEM fields only. Creative Computing is a discipline which allows, facilitates and furthermore, actively promotes the development of Creative Digital Skills across these traditional STEM/Arts barriers. This approach is seen as highly desirable by our interviewees – with general, all round programming skills in creative economy areas being seen as more important than high-level specialist skills in specific fields only. Again, we would not argue against the development of high-level expertise in tightly defined areas – far from it. However, it does appear that there is a great opportunity for delivering core computing skills, such as programming, AI, signal processing and machine learning, to those with skills that are not currently seen as relating strongly to STEM.

In making these observations, we are calling for a greater cross-fertilisation between Creative Arts and STEM disciplines. This can be achieved through the founding and better promotion of a larger number of Creative Computing degrees at both undergraduate and post-graduate level. However, alongside this, we would argue for establishing ways for undergraduate and postgraduation students to ‘minor’ in creative and applied computing programmes. This will reach a far larger audience across the creative sector, enabling large numbers of students to graduate with core programming and related skills that will greatly benefit them in the future, and also the economy generally.

Crucially, our data suggests a strong need for AI and Machine learning expertise across image, sound and interaction technology spheres. Data Science and AI conversion courses in the Creative Industry sector, in particular for those with backgrounds in the Arts and Humanities, will greatly benefit the Creative Industries, diversifying the AI skills based, and benefiting the UK economy as a whole. UAL CCI is currently in the final stages of delivering such a proposal in collaboration with large-scale industry partners.

Finally, we recommend the establishment of new SOC codes as part of the upcoming refresh of employment standards (the last SOC update was carried out in 2010). It is not sufficiently simple to hire Interdisciplinary technologists if recruitment companies, for example, do not understand that such employment categories exist. Specifically, we are calling for two new SOC codes: Creative Technologist, and Creative Programmer. We feel that this will be an important step to recognizing the crucial role that such employees have in the modern economy, and will help employers, academics, and policy makers better understand how the diversification of computing across the Creative Sector is impacting the working world.

Appendix 1

Semi Structured Interviews

Questions

- What Creative Technology skills do you think are most valuable in current Creative Technologists in your field?
- What Creative Technology skills are seen as most valuable for new employees in your organisation?
- How important do you consider programming to be to your organisation in the future?
- What computing disciplines (e.g. Signal Processing, Machine Learning / AI, Human Computer Interaction (can sub UX, UI, design there) Physical computing (say hardware prototyping / sensors if they don't get it)) do you consider most important to the future of your field / organisation?
- How important do you think basic programming knowledge is for creative technologists in their day to day roles? (1-5 rating if possible)
- How important do you think theoretical computing knowledge is for creative technologists in their day to day roles? (1-5 rating if possible)
- How advanced do you think professional creative technologist's programming skills need to be (1-5, 1 no skills, 5 very advanced skills) in their day to day roles?
- How important to you is it that your technology team / programmers / developers understand the core aims of your project / business / approach?
- What programming languages, if any, are of most value to your business?
    - e.g. C++ (include any frameworks e.g. OF), C, JavaScript (include HTML5/CSS and any frameworks e.g. react), Python, C#

- Do you find it difficult hiring Creative Technologists with the right mix of skills?
    - (Yes or no).