Studying marginalised physical sciences

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Introduction

The second half of the twentieth century offers distinct perspectives for the historian of science. The role of the State, the expansion of certain industries and the cultural engagement with science were all transformed. The foregrounding of certain strands of physical science in the public and administrative consciousness –nuclear physics and planetary science, for example – had a complement: the 'backgrounding' or neglect of a number of other fields. My work thus far in the history of the physical sciences has focused on this little-noticed intellectual terrain, and could be categorised into several types of case study that share distinct research questions, conceptual understandings and historiographical ramifications.

My attention for some years has been drawn to physical sciences that may have been identified as peripheral, if at all, by a previous generation of historians of physics. By this I do not mean peripheral in the geographic sense,[1] but marginal, interstitial or boundary-crossing in the context of occupations, disciplines and professions. The types of case study investigated include (i) scientific instruments; (ii) emergent professions or would-be professions; and, (iii) subject areas falling between academic science, industrial application and State interests. Within these categories are specific

[1] E.g. Filgueiras, Carlos A. L., 'The mishaps of peripheral science: the life and work of Manoel Joaquim Henriques de Paiva, Luso-Brazilian chemist and physician of the late eighteenth century', *Ambix* 39 (1992): 75-90.

studies of (i) Fourier spectroscopy and interferometry;[2] (ii) chemical and nuclear engineering;[3] and (iii) holography, photometry and colorimetry.[4] All have explored the nature of the working life of scientists and technologists.

This sense of ‘otherness’ is, of course, described in relation to definitions of inclusiveness or the mainstream. Thus the labelling of a subject as ‘interstitial’ or ‘boundary-crossing’ may be a matter of employing established practitioners’ categories, or historians’ conventional subdivisions. The establishment of a visible profession correlates only weakly with intellectual distinctiveness, or even with economic value. And, in some cases, the definition of the ‘marginal’ is no more than recognition of a lack of historiographical attention. These categories nevertheless can have profound consequences for defining research directions, for formulating organising explanations, and in setting certain constraints on research. There is also value in examining subject areas and scientific specialists that have been neglected by institutional bodies and historians alike, because I would argue that they may be functionally and structurally distinct from more established and renowned sciences.

Research questions surrounding emergent, marginal, interstitial and boundary-crossing subjects

In their formative stages, new sciences may emerge gradually from seemingly disconnected problems and research agendas. Some may be of ephemeral interest, and fail to coalesce into a new subject; others may thrive, attracting concerted and enduring attention; still others may be appropriated by disconnected groups of specialist and attain a perennial utility without expansive growth. The origins and

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[2] Johnston, Sean F., 'An unconvincing transformation? Michelson's interferential spectroscopy", *Nuncius* 18, fasc. 2 (2003): 803-23; Johnston, Sean F., 'In search of space: Fourier spectroscopy 1950-1970', in: B. Joerges and T. Shinn (ed.), *Instrumentation: Between Science, State and Industry* (Dordrecht, 2001), pp 121-41.

[3] Divall, Colin and Sean F. Johnston, *Scaling Up: The Institution of Chemical Engineers and the Rise of a New Profession* (Dordrecht: Kluwer Academic, 2000).

[4] Johnston, Sean F., *Holographic Visions: A History of New Science* (Oxford: Oxford University Press, 2006); Johnston, Sean F., *A History of Light and Colour Measurement: Science in the Shadows* (Bristol: Institute of Physics Publishing, 2001).

early histories of twentieth-century physical sciences have attracted the interest of historians and scholars of the social sciences because of what they can reveal about theory formation, the application of knowledge, and the importance of social and cultural context.

Young sciences, as well as those that do not follow the commonly recognised patterns of development – involving, for example, increasing numbers and types of scientific workers, establishment in university departments and external recognition by peers of their status as a viable profession – attract distinct research questions. My recent research on the history of holography, for example, suggested specific answers to some general questions: How are novel subject areas fitted into the ecology of knowledge?[5] What intellectual qualities attach to expanding subjects? What tactics can be pursued by practitioners to stabilise their occupation, to regiment their discipline and to promote their professional aspirations?[6] How can the early history of an emerging subject be recast by later events?[7] And what cognitive, economic and social characteristics correlate with definitions of ‘success’?[8] The subject that was eventually dubbed ‘holography’ in 1965 had coalesced from disconnected strands on ‘wavefront reconstruction’ at an English industrial laboratory, as an optical processing technique publicised as ‘lensless photography’ at an American classified lab and christened ‘wave photography’ by an isolated Russian engineer during his *Kandidat* research on imaging in Leningrad. Although judged a muddled concept and ‘white elephant’ during the 1950s, the subject was recast a decade later as a futuristic variant of photography and appropriated by engineers, artists and artisans for distinct purposes, generating new specialisms, art forms and industries. While its concepts broadened to seed much of modern physical optics, holography nevertheless did not establish a strong academic presence or long-lived journals. While this breadth of

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[5] Johnston, Sean F., 'Absorbing new subjects: holography as an analog of photography', *Physics in Perspective* 8 (2006): 164-88.

[6] Johnston, Sean F., 'Shifting perspectives: holography and the emergence of technical communities', *Technology & Culture* 46 (2005): 77-103.

[7] Johnston, Sean F., 'From white elephant to Nobel Prize: Dennis Gabor's wavefront reconstruction', *Historical Studies in the Physical and Biological Sciences* 36 (2005): 35-70.

[8] Johnston, Sean F., 'Attributing scientific and technical progress: the case of holography', *History and Technology* 21 (2005): 367-92.

communities, goals and applications may be unusual in its extent, its general features are, I believe, typical of sciences that emerge to straddle disciplines.

Some of these characteristics are shared with subjects that remain persistently on the borders of recognised sciences. An example of such intellectual marginality is photometry. The subject was hardly new in the twentieth century – indeed, the term was coined a century and a half earlier – but the first organised attempts to quantify light were motivated by the lighting industry and standardisation laboratories at the turn of the century, and separately by astronomers and physicists studying radiant heat. For each of these communities, the subject remained conceptually contentious; for example, should brightness be calibrated according to human visual perception, or by ‘objective’ physical instruments? It was operationally difficult, demanding the regimentation of human observers or deep understanding of the physics of photosensitive cells. And it was socially marginal, in terms of career coherence, status and progression. This cannot be attributed either to lack of research and organisational effort or dismissed with some definition of intellectual immaturity. Photometry continued to attract new sponsors through the twentieth century – notably the military, for radiometric detection of aircraft in the 1950s and by display engineers for calibrating illumination in the 1960s – but remained sidelined in university curricula and research programmes.[9]

A related example is the case of colorimetry, which through the twentieth century stabilised in what could be called an ‘interstitial’ regime. Like photometry, it assumed importance in commercial and standardisation terms early in the century, but attracted attention from two distinct disciplines: optical physics and perceptual psychology. The quantification of colour remained particularly contentious for these two communities, being best described according to the physicists as a physical or biophysical phenomenon, and by the psychologists as a psychological effect. The resolution of this impasse, by means of an interwar American committee, was an arduous affair based on extended debate and, eventually, a vote. The uneasy truce was certified by a jointly produced text in the 1950s and by the adoption of

[9] Johnston, Sean F., 'Making light work: practices and practitioners of light measurement', *History of Science* 34 (1996): 273-302.

international standards. The case suggests that subjects may reach an enduringly metastable state when shared between two established disciplines.[10]

Another case study having links to these forms of techno-scientific life is chemical engineering. This subject, unlike colorimetry, represents a case of successful boundary crossing. Identified at the turn of the century as an unpalatable and low-status hybrid of industrial chemistry and mechanical engineering, it attained disciplinary and professional status through a series of conceptual, political and pedagogical tactics between 1900 and 1960. Proponents differentiated the new subject from chemistry by identifying unique organising principles such as the ‘unit operation’, thereby making a case for university courses and, eventually, university departments.[11] They vaunted clear objectives for the new specialism that fit well with the political rhetoric of industrial and governmental initiatives to promote efficiency after the First World War and, even more persuasively, after the Second World War.[12] And, chemical engineers gradually usurped the tasks of other professions to establish their competence in post-war industries and increasingly mathematised university programmes.[13] The result of these manoeuvres was the establishment of chemical engineering as one of the big four engineering disciplines by the late twentieth century. The historical explanations for this ascent are heavily reliant on contextual

[10] Johnston, Sean F., 'The construction of colorimetry by committee', *Science in Context* 9 (1996): 387-420.

[11] Divall, Colin and Sean F. Johnston, 'Scaling up: The evolution of intellectual apparatus associated with the manufacture of heavy chemicals in Britain, 1900-1939', in: A. S. Travis, H. G. Schröter and E. Homburg (ed.), *Determinants in the Evolution of the European Chemical Industry, 1900-1939: New Technologies, Political Frameworks, Markets and Companies* (Dordrecht, 1998), pp 199-214.

[12] Divall, Colin, James F. Donnelly and Sean F. Johnston, 'Professional identity and organisation in a technical occupation: the emergence of chemical engineering in Britain, ca 1915-1930', *Contemporary British History* 13 (1999): 56-81.

[13] Johnston, Sean F., 'Identity through alliances: the British chemical engineer', in: I. Hellberg, M. Saks and C. Benoit (ed.), *Professional Identities in Transition: Cross-Cultural Dimensions* (Gothenberg, 1999), pp 391-408.

analysis that extends beyond the discipline and its practitioners, to explore what has been called the ‘ecology of the professions’.[14]

Describing, categorising and explaining such subjects

The varied cases that I have described can cross-fertilise each other. It has proven successful, for example, to consider classes of twentieth-century scientific instruments as special cases of what I dubbed intellectual ‘peripheral sciences’, a categorisation independently developed by Shinn and Joerges as ‘research-technologies’.[15] My own case studies of the associated cognitive domains of photometry and colorimetry are supported by others dealing, for example, with metrology, spectroscopy and post-war instrumentation.[16] This conceptual framework is important in recognising such interstitial or trans-disciplinary subjects not as failed fledgling disciplines but as occupying a long-lived domain hovering between academe and industry. As suggested by case studies to date, its associated scientific workers may represent a substantial proportion of practitioners in the physical sciences since the Second World War. Such fruitful avenues for historical and sociological research encourage further case studies of physical sciences during the late twentieth century focused along these lines.

My historical work on subjects as disparate as holography, nuclear engineering and radiometry also illustrates the well-established factors of post-war military funding,

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[14] Abbott, Andrew Delano, *The System of Professions: An Essay on the Division of Expert Labor* (Chicago: University of Chicago Press, 1988).

[15] Shinn, Terry, 'Crossing boundaries: the emergence of research-technology communities', in: H. Etzkowitz and L. A. Leydesdorff (ed.), *Universities and the Global Knowledge Economy: A Triple Helix of University-Industry-Government* (London, 1997), pp 85-96; Joerges, Bernward and Terry Shinn (ed.), *Instrumentation: Between Science, State and Industry* (Dordrecht, 2001)

[16] Mallard, Alexandre, 'From the laboratory to the market: the metrological arenas of research-technology', in: B. Joerges and T. Shinn (ed.), *Instrumentation: Between Science, State and Industry* (Dordrecht, 2001), pp 219-40; Hentschel, Klaus, *Mapping the Spectrum: Techniques of Visual Representation in Research and Teaching* (Oxford: Oxford University Press, 2002); Shinn, Terry, 'Strange cooperations: the U.S. Research-Technology perspective, 1900-1955', in: B. Joerges and T. Shinn (ed.), *Instrumentation: Between Science, State and Industry* (Dordrecht, 2001), pp 69-95.

industrial application and secrecy, all of which assumed considerably greater importance than they had had before the war. As a result, I have been drawn increasingly to investigate how these factors both constrained and favoured such subjects and further promoted the status of some of them as research-technologies. The profession of nuclear engineering, a current research focus, illustrates these special factors.

The nuclear engineer emerged as a new kind of technical specialist in the late 1940s in response to government initiatives around the world to develop atomic energy. The identity of these specialists – forming an unusually closed, State-allied discipline – was shaped in the context of post-war politics and energy programmes, and evolved along with popular perceptions of their subject over the following fifty years.

Unlike other engineering professions, nuclear engineers were defined by military requirements and were, during their defining years, a government monopoly in the first countries that fostered them, the UK, the USA and Canada. The first academic programmes appeared nearly a decade after the end of the war owing to secrecy concerns. Indeed, the minutes of their professional society in Britain, founded in the late 1950s, were only declassified in March 2007.

Nuclear engineers as a specialist community were also unusual in representing a social and intellectual ‘step-function’: the science and technology coalesced rapidly after the war and engendered professional aspirations from those diverted to work in the newly invented field. A comparative analysis of different national experiences in Britain, America and Canada is elucidating the distinct political and economic factors operative in those contexts. Americans, for example, favoured a putative division of military and civilian applications of nuclear energy as early as 1946, and encouraged the management and development of reactors by private firms. In the British context, weapons production dominated nuclear power programmes for the first generation of reactors, and industrial consortia proved unwieldy. Canadians, unlike their former allies, eschewed military applications, and pursued nuclear reactor concepts that did not emphasise plutonium production. The role of the nuclear engineer was envisaged differently in each country. The differing accounts of this new field generated by its practitioners, sponsors, historians and curatorial interpreters are also of considerable historiographical interest.

This growing collection of case studies has also suggested the vulnerability of physical science subjects that do not become securely established in a professional and disciplinary sense. Seen either as orphaned or dependent upon other 'host' sciences, I would argue that these marginal specialisms are unusually susceptible to redefinition or relegation based on judgements of audiences that extend beyond their peers in physics communities – for example, by industrialists, journalists and the wider public. These wider cultural evaluations, in the historical context of the post-war period, offer new opportunities for historical research.

Historiographical considerations

The examples of emergent and marginal subjects that I have identified in the post-war physical sciences carry with them methodological limitations and, perhaps, novel opportunities.

This can be illustrated again with the case of holography.[17] Consider, for example, some of the traditional resources available to historians of modern science: archival collections, deposited by retiring scientists or actively amassed by archivists of a profession, a university department or a company; museological collections, organised according to established criteria such as disciplinary categories, cultural relevance or professional interest; anecdotal accounts, written by practitioners and enthusiasts; oral histories, recorded and collected from the contributors deemed important to a profession; library collections of published books, papers and articles, preserved for current and future practitioners. It is obvious, on reflection, that each of these sources is constructed by disparate actors for identifiable purposes. Each embodies an intention or implicit understanding of how historical meaning is to be extracted. Thus the retiring scientist may wish to document his/her rising career trajectory leading to an acknowledged discovery or application; archivists, to preserve the heritage of their organisation; museums, to chart the progressive development of a commercial product or nationally significant invention; ethnologists, to record the

[17] Johnston, Sean F., 'Reconstructing the history of holography', *Proceedings of the SPIE - The International Society of Optical Engineering* 5005 (2003): 455-64.

personal insights of selected ephemeral actors; libraries, to provide an up-to-date resource useful for working practitioners.

This bias of the historical record is, of course, a commonplace familiar to historians. It is a much more serious problem, however, for subjects that either have never been widely recognised as progressive, application-rich or otherwise noteworthy, or have had a troubled evolution. Such subjects may never be documented adequately, because their practitioners never succeeded in establishing specialist journals. Or, the subjects may temporarily gain a foothold within current journal collections in libraries, only to be discarded a generation later when the profession fails to prosper and to attract faculty or new students. Its practitioners may never establish their scientific status adequately to ‘deserve’ archival storage by enthusiastic archivists or the funders of such collections; such practitioners may, indeed, wish to forget their ‘failed’ occupational diversions. And perhaps even worse, the subjects may be subsumed into more widely recognised research or developmental directions, with their histories inaccurately interpolated by a connect-the-dots exercise to yield an erroneous tale of founding fathers and breakthrough ideas.

In this respect, holography is a typical case in the domain of marginal sciences. The few institutional archives can be counted on one hand. They comprise the records at Imperial College of a Nobel Prize winner, Dennis Gabor, whose crucial early work is nevertheless substantially unrepresented, because he himself had discarded records of what he saw as a dead-end research idea; a moderate collection of files and holograms at the Massachusetts Institute of Technology, inherited from a bankrupt private New York holography museum, consisting of its business records and of holograms selected during the subject’s peak growth in the 1970s to represent ‘historic’ specimens but discontinued a decade later owing to faltering finances; far-flung files in Washington DC and at a handful of universities of government contract reports; and, in a few academic libraries, partial runs of practitioners’ periodicals. In short, the collected unpublished documentary evidence is sparse and widely dispersed.

On the other hand, physical sciences that have not attracted long-term attention as intellectual or commercial successes may have subtle advantages for historians, too: they may give the opportunity for an interpretation that is less actively biased by progressivist record-keeping. Practitioners may not feel compelled to impute success and incremental improvement to their field or life's work. This can liberate reminiscences and may afford relatively uncensored judgements.

Again, holography illustrates the potential advantages of this complementary side of a forgotten subject. Individual workers had, in a useful number of cases, preserved their private records. Business records, laboratory notebooks and collected ephemera were made freely available by retired and redeployed practitioners who had long ago abandoned expectations of profiting either financially or in scientific esteem from their experiences and expertise. A sense of community prevailed among the scientists and technologists who had spent often frustrating careers in the field, leading to a willingness to hunt down private collections of documents and long-lost colleagues, to provide candid personal perspectives on perceived failures and overlooked successes, and to assess the vagaries of their subject's trajectory. Artists and artisans, traditionally defined by their surviving products, were generous in trawling through their studios, basements and cupboards for unpublished formulas, letters and exhibition catalogues. Combining dozens of oral histories and privately and publicly held documents, the history of the subject proved to be dramatically different from its 1960s portrayal as high science; instead, it demonstrated gradually evolving theoretical ideas, appropriation by social groupings ranging from military engineers to artists to counterculture communes, and successive redefinitions as a military technology, a medium for self-expression and a fertile plot-device for science fiction.

Given the relative dearth of traditionally accessible source material, such marginal physical sciences demand changes in historical methodology. Published trails of research are of course available, but often migrate from journal to journal and may be difficult to track over the entire evolution of a conceptual development or career. Holography, for example, was reported in journals of general science during the 1950s, and then – in the absence of a disciplinary home – successively in journals of optics, electronics and optical engineering thereafter, redefining the scope of these fields as it was taken up by each.

For the marginal physical sciences after the Second World War, information is likely to be dispersed in classified or rare industrial reports, or to be found in boxes of private files destined for discard. This provides a serious constraint for the historian: to locate and access these documents while they remain available, or to convince companies and relatives that survive the document holders to preserve the records or have them archived. Again, to illustrate this problem with the case of holography, many such private document collections were located, but the attempts to locate archival homes for them were usually unsuccessful, even at major national museums. A notable exception is the American Institute of Physics, which nevertheless focuses on physicists, rather than engineers, artists and artisans practicing physics, in its admirable archiving and oral histories programmes. Given the limitations of storage space and available archival labour, it still remains necessary to justify the purpose for preserving the records of a marginal discipline and a ‘not-quite’ profession.

The only practical and faithful means of writing the history of holography has been to capture aspects of that history from the practitioners while they have still been available. This can open up a perspective on social history hidden to historians of other time periods. Oral histories amassed with techniques such as ‘snowball’ interviewing – collecting a broadening network of respondents by recommendation, reference or criticism – can reduce the tendency of historiography to favour elitist histories based on prizes, posts and other markers of professional status. Yet there is clearly an historiographical trade-off here: the advantages of privileged access to the historical actors and their unpublished collections for a brief historical window, tempered by the unevenness of sampling this resource owing to the vagaries of survival and availability of the actors and the scope of research travel of the investigator.

Direct interaction of the historian with practitioners can be ambivalent: on the one hand, the historical actors may provide direct (if often conflicting) personal accounts and interpretations of episodes; on the other, they may resent the interference of an outsider seeking to explain events in ways that may not actively support their interpretations or promote the subject as they would themselves. The historian’s account may conflict with others that inevitably suffer from selective recollection, and reshaping and rehearsing of events to satisfy simplified chronologies and accounts. As suggested above, however, subjects classed as ‘unsuccessful’ may offer an advantage for collecting oral histories: interviewees’ interpretations may be more candid and revealing than if they were seeking to vaunt their career successes in the field. And the interviewing of retired practitioners in such fields can obviate the need to promote a current research line or business proposition. Oral history remains unreliable for determining historical accuracy, but can provide valuable insights and important clues for locating and cross-correlating memories with documentary records. Oral history also explores a dimension unavailable in the analysis of published papers and only hinted at in the most unguarded correspondence: the historical actor’s perceptions and suspicions about facts and motivations. The revelation of such opinions and attitudes, while transient, can provide valuable clues for further historical exploration. The accumulation of these disparate forms of information can be a complex but fertile resource for the contemporary historian, and one that is richer than the traditional archival sources available to us.

Conclusions

My own research on marginal, interstitial and border-crossing physical sciences identifies distinct characteristics for their scientific and technical workers. Owing to sparse archival sources, these subjects require a shifted emphasis in methodological approaches, but also can provide consequent insights and opportunities that follow from them. The current generation of historians of science have unique prospects for studying the post-war and late-twentieth century period in directions unavailable to historians of other periods, but are equally likely to face challenges in accurately representing these half-hidden subjects.

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