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Client-facing Interprofessional Project Teams: The Role of Engineers' 'Situated Judgment'

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ABSTRACT

This paper addresses the type of engineering practice associated with 'client-focused interprofessional project teams' C-fIPPTs which is a typical pattern of work associated with engineering consulting companies. To do so, the article introduces the concepts of 'situated judgment' and 'immaterial activity' to the Engineering Studies community. It uses these concepts to demonstrate how engineers with different specialisms, working alongside architects, interior designers, etc., resolve competing conceptions of value among members to enable teams to accomplish project-specific issues. The article makes the above argument by drawing on observational data, interviews and field notes to illustrate the immaterial dimension (i.e. converting non-costed ideas into solutions to problems) of such situated judgments. The article concludes by firstly, explaining how the argument it advances about the distinctive features of engineering work contributes to a broadening of research on engineers work practice and, in doing so, the contribution that engineering studies can make to the field of workplace learning. Secondly, the article highlights the implications of its argument for engineering education and workplace learning.

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Introduction

This aim of this paper is to make visible to the field of engineering studies a form of work and its associated form of expertise that has been a growing trend in the global economy over the last twenty years, and to also highlight the implications of that trend for engineering education. This form of work is associated with 'professional service companies',[1] in other words, companies that specialize in selling their expertise to clients who have issued tenders to 'assemble'[2] project teams to accomplish outcomes specified in that tender. In a previous study of an engineering construction professional service company, we have characterized this form of work as 'client-focused interprofessional project team' (C-fIPPTs) activity.

In discussing this form of engineering activity, our article elaborates and extends a number of themes and issues that have been developed in the special issues of *Engineering*

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Studies devoted to 'Situated Engineering in the Workplace' and 'Engineering Work Practice' to, firstly, generate further insights into the dynamic and complex nature of engineering practice, the constant renegotiation of boundaries around engineering work, and the dynamicity of engineering expertise and identity. Secondly, we discuss the significance of the form of work being undertaken in engineering for cognate fields, such as workplace learning. In common with contributors to those special issues, our article adopts a practice-based and situated[3] perspective on engineers' work practice. However, it supplements contributions to those special editions in two ways.

The first is to analyze engineering work practice in accordance with Moulier Boutang's argument about the emergence of 'cognitive capitalism.'[4] The distinctive features of the cognitive dimension of work, according to Moulier Boutang are that, on the one hand, the most valuable workplace resources are the conversations, debates, deliberations and recollections of previous experiences that may occur face-to-face or be facilitated by computer-mediated communication, which inspire professionals with the same or different specialism to think imaginatively about how to tackle project problems. As a consequence, Moulier Boutang notes many companies have rearranged and reorganized work by dismantling functionally differentiated teams and replacing them with project teams to position professionals to collaborate with one another.[5] On the other hand, there is an 'immaterial' dimension to these conversations, debates, deliberations and recollections. In the case of engineering C-fIPPTs, we interpret Moulier Boutang's use of immateriality to mean, in contrast to other uses of the term,[6] the communicative activity that generates ideas etc. that are, at some point in time, converted into solutions: hence they were never stipulated and costed in the original project plan of work, though they clearly have material impacts. We acknowledge that, at first sight, the concept of immaterial activity may go against the grain of much previous research in engineering studies that has shown that the specificities of materiality always matter. We explain below why and how Moulier Boutang's concept of immaterial activity can be sees as consistent with, rather than a critique of, that body of work.

The second way that our article extends prior studies of engineers' work practice is by highlighting the distinctive form of engineering work practice associated with C-fIPPTs: the way in which members of C-fIPPTs make 'situated judgments'[7] based on immaterial considerations. By situated judgment, we mean the way in which members of C-FIPPTs commingle between different 'conceptions of worth')[8] (in other words, attachments to different values and priorities) when generating ideas about how to resolve issues with a project plan of work or problems arising from that plan.

Our article is structured as follows. It begins with an explanation of our conceptual frame, including the concepts of immaterial activity and situated judgment to establish why they can be seen as typical features of the work of C-fIPTs. Next, we explain our methodological approach by drawing on ideas from Actor Network Theory (follow the object), Social Anthropology (trace practice and context) and Cultural-historical Activity Theory (object as problem space). We then explain the context of work for C-fIPPTs in the construction sector, before discussing the interplay between immaterial activity and situated judgment. It presents this discussion of C-fIPPTs in relation to three modalities of their work: commingling competing conceptions of value; the generation of unresolved issues; and capturing externalities. It concludes by considering the implications of our analysis of C-fIPPTs for the fields of engineering studies and workplace learning.

Conceptual frame: immaterial activity, situated judgment, and conceptions of value

We outline our conceptual frame by explaining in greater detail our use of Moulier Boutang's concept of immaterial activity, contrasting his usage of this concept with Latour and Harman's different use of the same term.[9] We do so in recognition that contributors to engineering studies have for some time drawn on Actor Network Theory to highlight the 'socio-materiality' of engineering work and engineering research;[10] Harman's focus on the stabilizing and enduring qualities of objects may also be of interest to the field of engineering studies. Having done so, we then explain the provenance of our concept of situated judgment and its relationship to Moulier Boutang's concept of immateriality.

The cornerstone of Moulier Boutang's argument is that there is a general trend in the global economy where production is intimately tied to 'immaterial mediation.' He theorizes that the conjunction of production and immaterial mediation is producing 'cognitive capitalism'.[11] Immaterial mediation refers to the challenge of placing a monetary value on the generation of ideas, suggestions etc. These ideas and suggestions crop up, according to Moulier Boutang, because professionals' 'collective intelligence and invention-power' facilitates un-expected, but nevertheless, beneficial outcomes and, as such, has resulted in much work being organized so that professionals can work *with* one another for the 'capture of externalities.'[12] This phrase refers to professionals' generating by thinking aloud or through digital exchanges as they work together on ideas, data or knowledge, based on a mix of their different expertise, experience and technologies, and recognizing their value in the work process. Clearly, thinking aloud and digital exchanges are, indisputably, material or socio-material activities. What Moulier Boutang is highlighting is that the ideas, suggestions and recollections exchanged through these means of communication can be vague, speculative or misleading: hence their value is, at this point in time, indeterminant.

We have used this argument about the reorganization of work in accordance with the principles of the cognitive division of labor to highlight the way in which C-fIPPTs assembled by professional service firms, positions members of those teams to capture externalities to accomplish project goals.[13] The capture of externalities in this context refers to the generation of ideas, suggestions, recollections which may be picked up and used within a project or may be left 'on the table' to be used later in the project or another project or even totally discarded.[14] This immaterial activity represents, therefore, 'work beyond work', unexpected products which were not originally part of the costed brief but might be useful resources, either for this project, or ones in the future. We are not however assuming that every aspect of work in C-fIPPTs has an immaterial dimension and is concerned with capturing and trading externalities. Rather, such teams provide the context for this to happen.

This conception of immateriality is therefore rather different from the way in which, firstly, Latour uses the same term to discuss the 'immaterial' and 'material' dimensions of human interaction. He restricts the definition of the former term to a 'metaphorical framing' of interaction, in other words, a human generated form of constraint, before concluding that everything that happens in interaction or activation is, ultimately, material.[15] Secondly, the critique that Harman makes of the argument advanced by Latour and other ANT colleagues' that although objects are material, they are also 'contingent' and therefore lack boundaries of cut-off points. It is important, for Harman, to 'do justice to the reality of

objects', that is, their thing-likeness, that is, quiddity. He therefore invokes the immaterial to convey a very different idea, namely that objects exist 'at every scale of existence' and cannot be dissolved into effects or relationships.[16] Latour and Harmon's alternative conceptions of immateriality therefore offer valuable resources to analyze expressions of engineers' work practice in a different way from the perspective presented in this paper.

The sources of inspiration for our concept of situated judgment are Lave and Wenger's concept of 'situated learning'[17] and Boltanski and Thevénot's concept of 'conceptions of worth'. In the case of the former, we follow Lave and Wenger and accept that all forms of human activity are situated, however, this does not imply they are profession-bounded. It is, in other words, possible (as researchers have demonstrated for some considerable time) for members of different professions to use artefacts and dialogue[18] to communicate effectively with one another. We have however developed the concept of situated practices in a complementary, but different, way by drawing on Boltanski and Thevénot. They argue that: (i) human interactions rely on different forms of justification; (ii) there are always different conceptions of worth or value playing out in any situation; and, (iii) therefore it is inevitable that different types of justifications, ultimately, have to be reconciled with one another. Boltanski and Thevénot are concerned with justificatory processes within the political sphere and identify a taxonomy of different justificatory conceptions. The original taxonomy comprised: the *market* world – where value is measured by price and is the source of the accumulation of wealth; the *inspired* world – where value arises from the domain of art, passion and creative talent; the *civic* world – where value arises from serving the public good; the *domestic* world – which reflects family loyalties, heritage and hierarchies; the *fame* world – where value is measured by celebrity; and, the *industrial* world – where value is measured/ achieved by methodical planning; later, they added another world, *green,* where value arises from addressing sustainability issues.[19] We have, as we have explained elsewhere, 'recontextualised'[20] their argument in relation to the immaterial forms of activity that C-fIPPTs are engaged in to understand the way in which expert action is underpinned by different types of value, which emerge from forms of justification manifest in occupational or inter-occupational practice.

The context for this activity is the 'scope', that is, the project specific process (a fuller discussion of the scope occurs below) which positions members of C-fIPPTs to work collaboratively, but often intermittently and as such without a sustained track record of working together. In this context, communication processes tend to become simultaneous, multidirectional, and often reciprocal. The density and crisscrossing of these communicative processes and the sharing of information they generate, continually creates situations where team members have to find a way to resolve competing arguments about whether aesthetic, financial, technical issues (and no doubt in future green issues) should be the determinant influence on how they are going to resolve conundrums that crop up when working on the scope. We have conceptualized the way in which C-fIPPT's team members have to resolve competing attachments to different values and principles as a process of situated judgment. Such judgments have an immaterial dimension because as ideas arise and are tested out discursively, they may require teams to go beyond engineering standards and usual ways of working and, as such, have un-anticipated cost implications. Furthermore, discarded ideas have potential future implications. For example, an externality that can again be used in the future to solve another conundrum in the sense that team

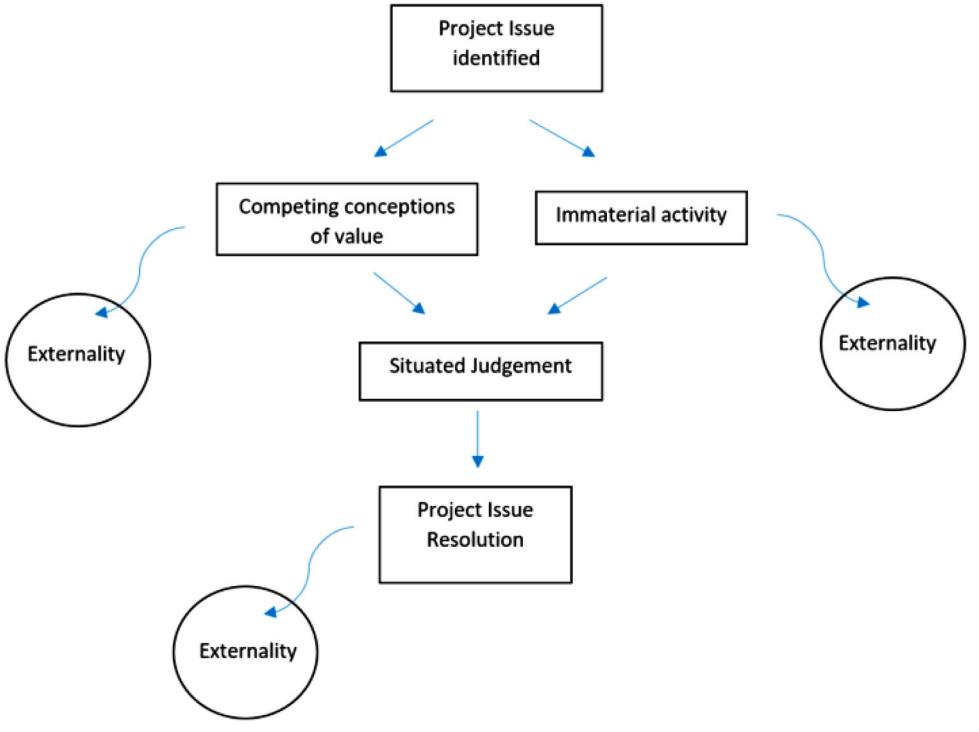

Figure 1. Externalities through project issue resolution.

members may recall their previous experience and proffer it in the following way – 'when we encountered something similar, we did this … '[21]

We present below in Figure 1 our immaterial perspective to highlight that its possible for externalities to emerge at multiple points throughout a project. We show through our data that as discussion shifts onto different areas, leadership rotates among team members during different phases of discussion as the implication of one conception of value is pursued more fully than another. The outcome of this process is that teams move on from 'thinking aloud' about an issue by choosing the predominant value for their decision and begin to commingle expertise, technologies, ideas, and data to form a view about which idea or suggestion to concentrate on. Immaterial activity, such as experience from previous projects and (re)affirming roles and responsibilities also enter into this step. Next is the collectively agreed way to proceed in this particular context to address the issues for the current project. This stabilization of the process of working can then be utilized in future projects to solve similar issues, and thus represents an 'externality', a resource for the team that is beyond the agreed plan of work. Secondly, the discussions and deliberations create a shared understanding of how the different conceptions of value may play a part in resolving an issue that the team is currently concerned with and is likely to assist in later issues given that the team now know each other's main concerns better than before. Likewise, the learnt ability to enter into problem solving and resolve these issues successfully constitutes a further externality for future use. As we show below, the reputation of a firm for being able to 'work well' with others makes them more likely to be included in future project bids.

Methodology and the project: student central

Our research is funded through a grant received by UCL Institute of Education's *Centre for Learning and Life Chances in Knowledge Economies and Societies* (LLAKES) from the United Kingdom's Economic and Social Research Council. The aim of the research is to identify the interplay between working and learning in C-fIPPTs since they are both a continually emergent, and under-researched, form of organizing work. The first two phases of our research started with identifying a professional services firm – a global engineering consultancy – *Dachell*. From our perspective, the way that the company had reorganized and rearranged work had many affinities with the features of cognitive capitalism described above. Via multiple scene-setting conversations with the executive team and then a series of hour-long interviews with engineers at the firm ($n = 6$), we initially focused on the activity they engaged in and subsequently drew on to secure repeat or new contracts by capturing externalities and making situated judgments. These discussions convinced us that *Dachell* represented a typical example of a firm whose work was undertaken by C-fIPPTs. The third phase, which is still underway, is the focus of this paper, and supplements the insights gained from the interviews by undertaking an extended observation of an interprofessional project selected from Dachell's current project portfolio of work, as well as in-depth interviews lasting between 1 and 3 h with individual members of the team (n = 8). So far, we have observed two design team meetings, each of roughly 3 h duration.

The intention is to provide a *situated* account of the nature of interprofessional project team working, to elaborate, or even challenge the insights derived from the interviews. The methodological approach uses Latour's famous dictum 'follow the object'[22], in our case project-specific goals, as a starting principle; however we recast this dictum within our respective interests in Social Anthropology and Cultural-historical Activity Theory. For the former, we respond to Burawoy's and Garsten and Nyqvist's[23] call for ethnography to trace processes through a focus both on what people *do* and the multifaceted influences on their actions, such as the role of client's interests and concerns, the health and safety regulatory framework. For the latter, we follow Edwards' argument that the object of activity constitutes the purpose of, and the problem space for, professional activity or work.[24] As a consequence, we have followed a specific project (described below) as it develops, focusing on key moments such as design meetings and conducting reflective interviews with project team members about how their understanding of the brief and the functioning of the project team progresses through the life of the project. The aim was to explore the project as an object that 'unfolds' through different processes, rather than as telescopic episodes, to investigate how professional work is done.[25]

Project team meetings were recorded, then transcribed to capture the specifics of the conversation, which are often technical. Fieldnotes taken during the meeting by the researchers focused on the actions, behaviors, and interactions between the project team. Both are used in the reconstruction of the team meetings to produce a rich account of the discussions. As we explain below, the project has been subject to a number of delays which has extended the intended project time frame. The two main project meetings that we explore in this paper, for instance, occurred in September 2017 and May 2018. It is worth noting that most projects take several years to complete and project team members are not consistently working on the project together all the time. Experts move in and out of the projects as their expertise is required, as specified in the plan of work (see below).

Analytically, our process has been iterative. Thematic analysis through primary and then secondary coding by both authors and extensive discussions of our first set of interview transcripts led to identification of 'immaterial activity.'[26] These forms of activity that go beyond what is costed as standard into a contract with the client who has commissioned the project might entail building and maintaining a relationship with the client or with project team members in other firms, or exploring within the flow of the project more creative or less financially costly ways to realize the commissioned project goal or an aspect of that goal. Our third phase of research aimed to identify evidence of these practices within project meetings. Thus, although on the one hand we were looking for something specific, at the same time, we recognize that much professional practice is likely to be 'taken for granted' by professionals and may not be explicitly identified by them in interviews. For this reason, we wanted to remain open to new ideas and concepts that emerged from the data.

The project the Dachell executives suggested for us to focus on we will call 'Student Central'.[27] The client is a prestigious English university. The brief is to refurbish and update a series of university buildings that surround an inner courtyard. These buildings are old and do not meet the current needs of staff or students. The project site is in an English city, which has buildings dating to the eighteenth century. The streets are narrow, the buildings tall, and in close proximity to one another. The aim is to open up the courtyard and develop a multi-use space that will house staff offices and researchers as well as an auditorium and teaching rooms. There was a concern to maintain the look of the existing buildings on the rest of the site. Due to its complex nature, and the need for many of the spaces to continue to be used during construction, the project has multiple phases which focused on different buildings in the courtyard. Thus, there are multiple stakeholders and users of the final product, and also an array of internal boards within the university structures, which have often meant long waiting times for decisions. The project has been on hold several times over the course of our involvement with it since August 2016.

The composition of the project team is also complex, combining extensive forms of expertise and interests. The architecture firm High-Arch won the bid from the university and has from five to seven architects of different degrees of experience working on the project, depending on the phase. Additionally, specific engineering specialisms are subcontracted to other professional services firms. Dachell was appointed to focus on the fire systems and to do specialist work on acoustics. Two structural engineers come from SFE, and three building services engineers (hereafter service or services) from the firm Jackson Hughes. The team is very international, including Europeans, New Zealanders, East Asians, and Britons. So far, we have interviewed project team members from these four firms, but there are also cost-consultants, project managers, and landscape architects involved in the project.

Client-facing Interprofessional project teams: context of their activity

Due to the large number of actors in large construction projects such as Student Central, who have been assembled via the tendering and contracting process, planning and organizing who is responsible for which aspect of a build is crucial. In the UK, the context for such work has been set by Royal Institute of British Architects (RIBA), in consultation with other construction industry partners, by producing a generic digital Plan of Work (PoW) as

a means to define the work process for complex projects. The PoW provides a central focus for the multiple firms that provide different expertise to organize a multifaceted form of working. The plan breaks a construction project into eight phases and specifies the main tasks and objectives as the project moves from the brief, through different design stages to construction and use. It is customizable rather than prescriptive. It is a digital tool C-flPPTs deploy to facilitate project teams who are located in different cities, companies and disciplinary specialisms. The project team members will have differing levels of involvement as the construction project moves through different phases. Typically, buildings services engineers and structural engineers stay with the project for most of the time whereas fire and acoustics engineers only contribute at particular moments when their expertise is required.

Alongside the PoW, the project team agrees the 'scope'. This term denotes exactly how C-flPPTs translate the generic PoW framework into a project-specific work process which specified what each team member is responsible for producing and delineates the associated cost. It is thus crucial for establishing how the parameters of the contract agreed with the client are distributed across the project team. The PoW and the scope are what organize a disaggregated collection of expertise around a core purpose.

The scope, as an agreed specification of work to be completed within an agreed budget in a particular phase of the life of a project serves several functions. It specifies the cost attributed to each group or personnel and states what work they will produce, enabling budget management and helping diverse and multi-located project teams to organize their work responsibilities. This facilitates professional working by demarcating roles and making expectations clear to the client. It is particularly important for projects with firms that have not worked together before. Thus, its second function is to stand instead of a pre-existing working relationship since the project team assemblage process may result in a considerable number of members who have never previously worked together. As Daniel, an architect who took part in our initial interviews explained,

> Daniel: When you've worked with them before you build up the relationship, you know 'oh these guys never do the drainage', or 'these guys always do … ' you know, you don't to have to check those scopes, you can just quote your work, you know the whole building's covered.

Thus, for newly formed teams the scope is crucial for ensuring all parties are clear as to who is responsible for each element, and that every task is duly allocated. When a new team works together for the first time, more labor is required to develop those demarcations in the working practices. This can mean that:

> Daniel … you're with two people that you've never met before and you're thinking 'oh OK, we'll see how this works'. But you can define roles and responsibilities and the scope allows you to form a professional relationship with whoever you're given it's feasible to do it in a professional way. If you've not worked with them before knowing exactly what they're going to do and when they're going to do it, that's the thing.

At first look, both the scope and the plan of work appear to maintain the classic assumption about the boundaries of professional jurisdiction,[28] as the distinct phases of the plan of work, where the architect and client bring in different forms of expertise and professional knowledge at different points, thus implying linearity and separation. This is however not quite the case. It takes, as Daniel highlights, work to establish 'who does what' and 'how it is done' but this work is not costed. Thus, this activity of figuring out responsibilities, which is essential for the smooth running of a project, is immaterial despite having

ongoing material consequences, both in monetary terms and in the actual construction of a building. Although co-ordination artefacts such as the plan of action and the scope imply clear lines of delineation, as we will show in our case study, the reality of working demonstrates that there are always overlaps, and situated judgment is required to resolve project issues that arise in those overlaps or intersections. While domains of expertise and forms of professional knowledge are represented by engineering specialisms, for example, civil, mechanical, structural etc., which remain distinct, knowledge is deployed in a multifaceted setting, where the walls must necessarily interact with the pipes and thus engineers from different specialisms as well as the architects and the client are positioned to work together and agree. Nevertheless, team members are likely attached to different conceptions of worth or value, represented by their expertise and professional values, for example, the extent to which they emphasize aesthetic over technical or financial considerations. The invocation of these influences offers a texture to the way in which members contribute to their team's collective deliberations and, in doing so, form situated judgments.

We show, via three excerpts from team meetings, different examples of the ways in which situated judgment is necessary to resolve project issues. We firstly use one example to demonstrate how the *commingling* of conceptions of value, such as balancing aesthetics with practical concerns of the building's structural strength, the delivery of necessary services and the cost implications, enables the project team to reach a situated judgment. We then illustrate how team members' intermittent engagement with the scope generates unresolved issues, before concluding by showing how competing conceptions of value are reconciled.

The scope: commingling competing conceptions of value

Design team meeting central London offices of High-Arch architecture firm

In this meeting, Fabrizzio, one of the structural engineers, is explaining to Tymon, an architect from High-Arch, about a range of manufacturing options for the structural beams for different parts of the Student Central building. As the project is further along than in the previous team meeting, a cost consultant, Carl, is also present to assist with making situated judgments.

Fabrizzio: So we did some analysis on the size of the columns and setbacks at the roof level. We gave two options essentially. There are two zones, Zone 1 and Zone 2. So for Zone 1 we have two potential options, one is an option with two front plates connected by the central bar which of course is a more efficient construction. And then the yellow ones [referring to a colored section on the drawings] we have two options. It's the length. You see they're 180×50, so it becomes longer. And then as you make it thinner they grow in length. Because essentially it becomes very flexible. So this is for Zone 1. Zone 2 we have these options which are $100 \times 10 \times 30$ for these options, 100×40, 170×50 and we will run a system of beams to support it.

Tymon: OK, well we will have a look at these and we will let you know which one we prefer. OK.

The discussion here is about different conceptions of value, in this instance, the relationship between aesthetics and technical options. The structural engineer's job is to articulate, from their professional expertise in their specific area, what will hold the building up, to match the aesthetic the architect desires and to still be cost effective while accepting that the architect will make a final decision on the suggested options. Initially, it appears as though Tymon's comment 'we'll let you know' is going to close the discussion down. Fabrizzo, however, carefully points out that up to now the discussion has been only focusing on the roof level. He and Tymon then adopt a wider perspective on the relationship between aesthetic and technical considerations at different levels in the building:

Fabrizzio: So this is at the roof level. At ground floor when we look at the main columns there are two ways of following these columns, either adding a pre-fabricated section which is an RHS specially made, which is the one by 600.

Tymon: Because at the moment, the proposed one is kind of 50 × 650 and we try to make it smaller to 600 × 200 so when we clad with stone we can have it slender.

Fabrizzio: Yeah. So we can make it slimmer as we want, it will grow in thickness and so weight, this can be achieved with an RHS pre-fabricated, or taking the UB section and then welding two plates here and here. I guess in terms of cost it might be similar in terms of workmanship because when you start welding plates the cost of the RHS is the same cost as this. And the difference would be the actual weight essentially.

Eventually, Fabrizzio introduces the issue of cost and this leads Tymon, Fabrizzio and Carl to address the relationship between aesthetic (what it looks like), technical (weight loading), cost spectrum (in or out of budget) considerations.

Tymon: And how much more expensive is it from our current proposal, just in terms of 50 × 650, which I think if looking like this on it, the kind of proposal level, is it the same? Because we just wanted to know how much that will cost now.

Fabrizzio: I'll get back to you in terms of the weight, I don't have the formulas of the weight, it will go up proportionately and decrease in the tonnage. [To Carl, the cost consultant] What are the differences between the cost of tonnage of a fabricated section versus.

Carl: Well it can vary a lot. I mean I think generally from about £2,250 for UBs. And I think then its hollow sections and it goes up a bit. Fabricated, probably got 4 maybe, or 3 to 4 thousand.

The above conversation extract illustrates both the complexity of decision making when aesthetic, technical and cost considerations have to be commingled, but also the temporal basis of that process: a final judgment is postponed until the cost implications in relation to the allocated budget in the scope are known.

A similar tension between aesthetic and technical standards is noted by Faulconbridge et al.'s work with building designers working on commercial offices for speculative sales.[29] In the case studies they explored, a third factor came into play, the need to design offices to a 'market standard' which increased the value of the property and the likelihood of profitable sale. Their study notes that this adds a constraint to building design due to the need

to comply with the 'cultural logics of 'quality' and 'legitimacy'. This causes considerable friction between architects, engineers, developers and letting agents who each blame other parties for the necessity of compliance to this conception of value that often supersedes innovation or client need.

Our case has, however, not revealed this type of frustration. This may be because Student Central is a bespoke project that will not float on an open market and thus the brief is attuned to the needs of the client, rather than a normative conception of saleability. In project team meetings we have observed, however, that team members navigate their way through these conceptions of value through making situated judgments. Here Fabrizzio lays out the different options, and with Carl's assistance in estimating the cost, the team is able to weigh up the aesthetic vision of the project via Tymon's input, against the cost of different structural options. This is a complex process. It starts with immaterial mediation in relation to which aspects of the different conceptions of value are in play – aesthetic, technical, financial – as team members think aloud about various issues that crop up in the course of realizing the scope. It then goes through various deliberations, some of which are inconclusive and left on the table, before eventually resulting in a situated judgment. This outcome (in Schön's terms[30]) 'wasn't in the book', in other words, it wasn't a known and well tried and trusted way of doing things.

The scope: unresolved issues

One of the dynamics of C-fIPPTs is that some team members move in and out on a regular basis throughout the course of a project, with the result that issues can remain on the table for later resolution. We illustrate this issue through reference to the contribution of a fire engineer. Within the Student Central project, *Dachell*'s fire engineers were specifically contracted to overcome complex difficulties in the design of the fire strategy. The age of the buildings and the narrow entrances to the courtyard present an issue of access for fire engines, and as the buildings are very close together containment (i.e. preventing fires from spreading) is also tricky to manage. Chara, a fire engineer, was brought in at RIBA stage 2 and explained in an interview the specifics of her role:

> Chara: So what we do as fire engineers is, we do design, we don't do any specifications of products, we don't recommend products unless we are asked, and it's not part of our scope … We do what is needed to be done for fire and that's where our scope works. Also if we agree on a scope of works we are very strict to keep that scope of works. Sometimes, for example sometimes we overlap with mechanical engineers or electrical engineers because we say 'you need a specific alarm system in the building' and they come and say 'OK, tell us where'. Yes but we don't design these, we just tell you the type of the system that needs to go, you design that. And then we review, we can review the design and see if we are happy or not. So that kind of overlaps.

As Chara's work as a fire specialist is so specific, she does not attend every project meeting, but rather attends only at key moments when it is expected that her expertise will be necessary. Staying within the bounds of the scope is important because this is all that is costed. However, we observed in the following design team meeting a situation when a

project issue remained unresolved. While the team spent some time discussing the various options, they were not able to reach a situated judgment because they required additional expertise from Chara, who was not present, as extracts from our fieldnotes demonstrate below:

Design team meeting, Central London offices of High-Arch Architecture firm

> Towards the end of a design team meeting, James, a service engineer, asks about when construction moves to phase 5 of the build, when a part of the building will be closed off in order to carry out the refurbishment construction work. As this currently has entrances to the geography and zoology departments, he wants to know about the arrangements in the event of a fire as this will also impact upon the route of the services. The different sections are labeled on the drawings as orange and blue and the whole team begin to discuss who has access to each part of the building during this phase.

The discussion involves the architects, the service engineers and the structural engineers because the different options rely on the 'compartment line,' i.e. a fire retardant break between the two areas, such as a wall, and the services has to be delineated for safety reasons. Here some of the health and safety functions of the building are balanced against the aesthetic aspirations and technical requirements of the ongoing construction project. This is a particular and ongoing issue for Student Central as the buildings need to continue to partially operate while the refurbishment is carried out.

> As usual the project team utilize the paper plans of the building, with many comments to clarify which section is which, what 'this bit', or 'that line' refers to. The main issue is centered on if there is a fire in one section, whether the other area would need to be notified by a fire alarm, or should also evacuate and where fire panels that control the alarm systems will need to be placed so they are accessible by the right people.

Thus, these material specificities are immaterially mediated in the project team's discussion of the options. Team members explore what will be necessary due to the other aspects of the building and the construction work again as they balance different conceptions of values. This balancing, of course, should involve Chara, as the fire engineer, but she was not present at this meeting. Project team members are, as we have shown, keen to 'make it work' and will go beyond the bounds of the scope for the right client, to develop a relationship, or because they are inspired by the project.[31] However, the constraints of C-fIPPTs mean that Chara's involvement in this particular phase was not in the scope. As she was not present at this meeting, the team decided not to take a final decision or discuss all possibilities without her input and instead to proceed with other aspects of the scope.

The scope: capturing externalities

We have seen in the previous examples how firstly the value of aesthetics was balanced with technical and practical needs of the building, and with cost. We have also shown how, when the right person with the necessary expertise is not in the room, issues remain unresolved as a fully situated judgment cannot be reached. In this final example we show how two further values, the intended use of the building and the logistical challenge of ensuring the building has appropriate services, requires the whole team to 'think aloud' before they can make a situated judgment.

Design team meeting central London offices of High-Arch Architecture firm

This discussion focuses on how to preserve enough space in the rooms for their intended use, while ensuring that these spaces are adequately temperate and can also fit the pipes and ducts needed to fulfill this goal. Catherine, a service engineer from SFE, talks the team through the options that they have explored through modeling the ventilation and cooling of the small teaching and seminar rooms. She explains that the only reasonable option they have come up with means that a cupboard in one of the tutorial rooms is going to be very full of pipes and ducts, reducing the usable space in that room.

Catherine: So then we looked at using chilled beams, so similar to what we've got in CRB, and that seems to work if we have some of the fresh air requirement done by a handling unit or two handling units in the plant room and then additional active chilled beams in each of the spaces to provide the initial cooling load. The coordination is complicated as you may be able to see from some of the specifics on Revit [the modelling software] that I've brought today. There's a bit of duct work spaghetti going on in the cupboard of the first tutorial room, which seems to happen no matter what we do just because of the height difference obviously between where the plant room is and where the ceiling height of the tutorial room is. So I think that first cupboard is always going to be quite full of services.

These observations lead the team to discuss other options, Catherine suggesting that they could take a bit of space from a toilet instead, but Rowan (Architect and Project Manager) stating it is already rather small. Various options are discussed but they all still mean the cupboard needs to be bigger, reducing the amount of teaching space:

Tymon: Could we assume that this is planned so it can be completely final, but it [pointing at the cupboard on the drawing] doesn't have to move forward?

Caroline: We need to look at that. With this option it's close. We might have to take a little bit more space in that one room. It should be fine in the other rooms, it's just that first one.

Nicos: We think that we'll still need to cross two main ducts in the first cupboard. And so we are trying to see how much space this needs.

As they discuss these options, they draw on the paper available on the top of a desk demonstrating what each option would mean for the space. On the one hand, paper copies seem an old-fashioned way of proceeding as they are, unlike digital resources, incapable of being endlessly revised and shared; but on the other, the immediacy with which these can be marked up with proposed ideas means paper copies remain very useful for the rapid fire discussions that characterize the design team meetings, as they enable the team to see visually how an option affects the space.

Following several rounds of thinking aloud and sketching implications from different perspectives, Rowan (prompted by that thinking) puts forward the following suggestion:

Rowan: I'm just thinking, what about if because we've got this roof lights landing on the roof here anyway. What if we and I don't quite know whether this would work or

> not, but what if we just extended that through and created a kind of pop up to these three rooms that had access to ventilation at high level. And/or you could just do window extract only with natural ventilation.

Catherine confirms, that with some additional cooling, that is an option that they can investigate. The discussion continues, exploring how much space the position of the structural beams will leave for ducts and pipework along the new route they have suggested. Eventually, the team runs out of time, and Catherine will need to do some more work on her own to model the new suggestions and consider how to fit what is needed around the structural support beams. The discussion relies a great deal on consulting the drawings on the table checking dimensions and the lines of services through the building, and the location of windows and roof heights. Again, this requires the expertise of all the team present – the service engineers, the structural engineers, the architect, and at this later stage, the cost consultant.

The above example sheds light on the un-expected, but nevertheless, beneficial outcomes accruing from immaterial mediation via the capture of externalities. The resolution of the ventilation and cooling conundrum occurred after several rounds of idea generation before Rowan put forward another idea that the other project team members present in the meeting all felt would work. The resolution constitutes therefore an immaterially mediated situated judgment because, on the one hand, it is an example of what we referred to earlier as work beyond work (i.e. unanticipated and un-costed in the PoW and scope); and, on the other hand, although the resolution 'works' on this occasion, it is not necessarily replicable on another occasion.

Client-facing Interprofessional Project Teams and situated judgment: implications for engineering studies

The focus of engineers' work presented in this paper is C-fIPPTs. This form of work has been, as we have explained above, a growing trend in the global economy for the last twenty years. It is characterized by the traversalisation and circulation of knowledge, the capture of externalities and the formation of situated judgments to accomplish project goals and is associated with professional service or consulting firms. What is distinctive about these types of firms is that they compete for contracts from clients globally, and the contracting process results in the creation of C-fIPPTs that will exist only for the life of a project. C-fIPPTs nonetheless work with national project planning frameworks, for example, RIBA Plan of Work, and their project-specific interpretations and realization, for example, the scope. Our case study is therefore a typical example of this form of work in relation to (a) the contract procurement process (b) the construction of C-fIPPTs and (c) formation of situated judgments and engagement in immaterial activity.

This form of work therefore has some affinities with and some differences from the account of engineering work presented in Styhre's book *Managing Knowledge in the Construction Industry* and of freelance work presented in Barley and Kunda's *Gurus, Hired Guns, and Warm Bodies: Itinerant Experts in the Knowledge Economy*.[32] Both texts share a common emphasis on the traversalisation and circulation of knowledge. Where they differ from our paper is that we focus on the immaterial and situated dimensions of that process. We focus on, in other words, the way in which solutions to problems arise out of the commingling of

different forms of professional specialisms as members of C-fIPPTs think aloud. In contrast, knowledge circulation is treated as the process by which key individuals provide solutions to problems in Styre and Barley and Kunda's texts. We explore the contribution of our article to the field of Engineering Studies more fully below through a discussion of how our concept of situated judgment offers a new angle on aspects of engineering work compared to the contribution made by such classic texts as Bechky's article 'Object Lessons: Workplace Artifacts as Representations of Occupational Jurisdiction,' Kunda's *Engineering Culture: Control and Commitment in a High-Tech Company*, and Casey's (1995) *Work, Self and Society: After Industrialism*.[33]

Our concept of situated judgment brings, as we noted above, the influence of competing conceptions of value, for example, aesthetic, technical, financial etc., to the fore. The concept therefore allows us to take account of the textured nature of interprofessional work, as well as revealing how the collective engagement with different objects, in our cases paper-based ones, facilitates firstly the immaterial thinking aloud process we have described. Secondly, enables C-fIPPTs to make situated judgments.

The work contexts we have researched present a stark contrast to previous work that has explored the role of artefacts in facilitating situated judgments in engineering work and more broadly in the field of workplace learning (Malloch et al. 2021). Take, for example, Bechky's well-known case study of a semiconductor manufacturing plant, which explores how in this hierarchical workplace, objects and the workers maintain strict boundaries. In this context, engineers occupy the top of the hierarchy and produce the technical drawings. These are passed down through the hierarchy to technicians who then build the product. The objects Bechky discussed were therefore the outcome of profession-specific vision[34] and, as such, made in isolation and then passed from one profession to another or up and down a professional hierarchy.

The objects we refer to above are very different: they are co-generated, co-discussed, co-enacted. These processes sometimes played an organizing role and result in un-resolved issues and sometimes in immaterial outcomes, in other words, an unexpected solution to a problem. The reason for the difference is that Bechky's engineers and technicians all work in the same firm and in a stable hierarchy, and thus constitute an organizational community of practice. Our concept of situated practice, learning and judgment is rather different. The difference in the conception of situatedness rests on the relative stability and homogeneous character of a community of practice compared to the relatively contingent and heterogeneous character of a C-fIPPT, including its client-facing focus. Our research participants work in different firms, on short term projects, where their future business relies on them getting on with each other and producing the work and actively involving the client who commissioned the project in discussions about progress towards project goals.

This observation anticipates another issue about our concept of situated judgment. We have demonstrated in this paper how the justificatory practices that underpin a situated judgment are, themselves, a situated accomplishment, because they are learnt and deployed within the context of project team working. Project team members had to justify their suggestions on the basis of how it affected other aspects of the building – deploying interprofessional situated judgment, the commingling of judgments to enable a team to negotiate how to address issues that cut-across expert-systems, rather than draw jurisdictional boundaries and only interact at points of 'dispute'. As Chara acknowledges, 'It needs

to all connect actually, it needs to connect to all the building, all the elements of the building you cannot just do it one by one.'

This is of course a nuanced process. Nevertheless, as one of the directors at High-Arch was keen to point out to us, when we spoke to him about wanting to understand how knowledge was negotiated amongst a team to reach a conclusion, he stated very clearly that the project team is 'Not a democracy'. There are also legal implications for signing off work and a very formal process of passing on the model and the ownership of the model at different stages. In drawing our attention to the issue of democracy, the director was, inadvertently, also drawing our attention to a dynamic associated with C-fIPPTs: they have rearranged and reorganized, rather than entirely dismantled, the notion of professional jurisdiction based on expert knowledge. Certain domains of work are still legally associated with particular professions; and those professions have executive responsibility for guaranteeing standards of performance. What is deceptive about this summative professional responsibility, as have highlighted in the paper, is that it rests on a series of interprofessional situated judgments rather than solely the demarcation of profession-specific jurisdiction. It is also vital for firms engaged in C-fIPPT work that their employees are skilled at making situated judgments and avoiding conflicts, as these are the traits that will result in future invitation to collaborate on bids and secure repeat work.

We conclude therefore that our concept of situated judgment offers a nuanced and textured way to understand the work of C-fIPPTs and interprofessional work not only in the field of engineering studies, but also the field of workplace learning.[35] Here, discussions of interprofessional practice tend to be concerned with intervention studies to 'expand' forms of activity, 'knotworking' within organizations or the formation of 'common knowledge' among stable team members[36], rather than the contingent and intermittent forms of work represented by C-fIPPTs.

In making this argument, we see our article as supplementing the classic assumption made by Abbott that professions axiomatically exercise jurisdiction over aspects of the work and the subsequent argument that control of work brings conflict between professions. Our argument is that professional jurisdiction is context-sensitive rather than context-independent. We contend therefore that we are supplementing the way in which the field of Engineering Studies could engage with the diversity of engineering practice: new engineering work contexts presuppose new conceptual frameworks to analyze new engineering work practices. We nevertheless recognize the enduring validity of the insights accruing from Kunda's study on corporate culture and normative control as well as Casey's study of self-formation and corporate culture that arise from discursive practices of work, which will continue to apply in other work contexts.

Conclusion

We return in the conclusion to two arguments we introduced earlier in the paper: one relates to our framing argument and the other to our empirical examples of C-fIPPT engineering practice. In the case of the former, we have proceeded from the assumption that the reorganization of work associated with cognitive capitalism both positions professionals to collaborate and intensifies this process. We have explored this contention in relation to engineering through reference to the concepts of immaterial activity and situated judgment to explore a particular context in engineering, where engineers working

for professional service or consulting firms are positioned to work with other professionals to decide how to address project-generated issues. We have noted conceptually and empirically how this development has simultaneously extended and reinforced interprofessionality. In the case of our empirical evidence, which is an exemplification of the above trend, we have shown that a final situated judgment, which may occur within a jurisdictional boundary or a spanning of that boundary, rests on a series of interprofessional immaterial deliberations rather than the axiomatic demarcation of professional jurisdiction. This outcome is a reflection of the relatively contingent and heterogeneous character of a C-fIPPT.

In reflecting on our argument for the education of future engineers who will work in C-fIPPT contexts, it is important to acknowledge the existence of two options. One is to continue to educate engineers in accordance with the value and practices associated with longstanding engineering specialisms. The other is to develop interdisciplinarity through measures such as project-based learning in engineering degrees in an attempt to attune future generation of engineers to the conditions and nature of much contemporary work. The former presupposes it is then the employers' responsibility to enculturate engineering graduates into their operational culture. The challenge of 'working across disciplines' to 'problem solve,'[37] which is associated with the latter, has long been recognized as a major concern in Engineering Education. One well-known, but not necessarily widely taken-up, solution is the introduction of project-based learning in engineering degrees to facilitate the development of interdisciplinarity. This option has always begged the question – what form should project-based learning take? Both the traditional and project-based learning options for the future education of engineers require sustained consideration in a future paper for slightly different reasons. In the case of the former, the 'gap'[38] between engineering education and industry remains a recurring topic of discussion generating new suggestions as regards how that gap may be closed. Some recent articles in *Engineering Studies* have shed light on the complex manifestations of this gap. They have, for example, revealed the possible mismatch between engineering courses that have developed multi-disciplinarity, culturally competence, and/or environmental consciousness that do not necessarily conflict align with certain industries or job roles that engineering graduates may enter, and the intersectional challenges that women might encounter via their organizational socialization experiences and how they impact on their career outcomes.[39] In doing so, the articles raise implicitly the extent to which engineering courses can ever be expected to prepare students to address and full range of school-to-work' challenges that they will encounter. In the case of project-based learning, current models[40] have not been designed to engage with our argument about the immaterial dimension of some engineering in the work contexts we describe – whether this is possible is an open question.

Notes

1. Empson et al., *The Oxford Handbook of Professional Service Firms*.
2. Law, *Aircraft Stories*.
3. Nicolini, *Practice Theory*, Lave and Wenger, *Situated Learning*, Orr, *Talking About Machines*.
4. Moulier Boutang, *Cognitive Capitalism*.
5. Ibid.
6. Guile and Wilde, "Articulating Value," 520.
7. Ibid., 326.

8. Boltanski and Thevénot, *On Justification*.
9. Latour, "On Interobjectivity;" Harman, *Immateriality: Objects and Social Theory*.
10. Styhre et al., "Sociomaterial Practices in Engineering Work" and Johri and Olds, "Situative Frameworks for Engineering Learning Research."
11. Moulier Boutang, *Cognitive Capitalism*, 33 and 53.
12. Thrift, Introduction to *Cognitive Capitalism*, viii.
13. Guile and Wilde, "Articulating Value," 526.
14. Ibid., 328.
15. Latour, "On Interobjectivity."
16. Harman, *Immateriality: Objects and Social Theory*.
17. Lave and Wenger, *Situated Learning*.
18. Suchman, *Human-Machine Reconfigurations: Plans and Situated Actions;* Akkerman and Bakker, "Boundary Crossing;" Winsor, "Rhetorical Practices" and "Knowledge Work."
19. Thevénot, Moody, and Lafaye, "Forms of Valuing Nature."
20. Guile and Wilde, "Articulating Value," 324.
21. Boltanski and Thevénot, *On Justification*.
22. Latour, *Science in Action*.
23. Garsten and Nyqvist, *Organisational Anthropology*; Burawoy, *Global Ethnography*.
24. Edwards, "A Cultural-historical Approach to Practice."
25. Foot, "Pursuing an Evolving Object."
26. Guile and Wilde, "Immaterial Activity."
27. All names, both individual and organizational are pseudonyms.
28. Abbott, *The System of Professions*.
29. Faulconbridge et al., "How Market Standards Affect Building Design," 639.
30. Schön, *Educating the Reflective Practitioner*.
31. Guile and Wilde, "Articulating Value," 320.
32. Styre, *Managing Knowledge*; Barley and Kunda, *Gurus, Hired Guns*.
33. Bechky, "Object Lessons;" Kunda, *Engineering Culture*; Casey, *Work, Self and Society*.
34. Goodwin, "Professional Vision."
35. Malloch et al., *Sage Handbook of Workplace Learning*.
36. Engeström, *Knotworking*; Edwards, "A Cultural-historical Approach to Practice."
37. Adams and Forgin, "Working Together Across Disciplines;" Jonassen, "Engineers as Problem Solvers."
38. Alboaouh, "The Gap Between Engineering Schools and Industry."
39. Beddoes, "Examining Privilege;" Brunhaver et al., "The Early Career Years of Engineering."
40. Graham, *Global State*.

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