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Abstract

This paper is primarily concerned with exploring the technical and social dimensions of problem solving undertaken by technical staff in a Pacific Island radio station. Essentially, the paper addresses the question "what influence do physical and social contexts have on engineering knowledge development?". The paper notes that the concept of context is not given significant attention when looking to dominant philosophies of engineering. This stands in contrast to the importance accorded to context in development literature, particularly in relation to technological knowledge. Using Macdonald's research into the role of information in innovation, the paper identifies a number of factors besides isolation that constrain access to problem solving information; namely, organisation size, poor commercial relationships, absence of interpersonal contacts with experts and unrealistic expectations of newly qualified engineers. This analysis points to a broader set of challenges than is often accepted in the training of engineers in small island economies: that is firstly of the sufficiency of theoretical knowledge and secondly, information being widely available and easy to transport by communication technologies.

Keywords

teaching, telecommunication engineering education, training

Disciplines

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KEEPING A GLOBAL TECHNOLOGY WORKING: A STUDY INTO THE SOCIAL AND TECHNICAL DIMENSIONS OF BROADCAST ENGINEERING IN THE PACIFIC ISLANDS

William Tibben¹.

Abstract — *This paper is primarily concerned with exploring the technical and social dimensions of problem solving undertaken by technical staff in a Pacific Island radio station. Essentially, the paper addresses the question "what influence do physical and social contexts have on engineering knowledge development?". The paper notes that the concept of context is not given significant attention when looking to dominant philosophies of engineering. This stands in contrast to the importance accorded to context in development literature, particularly in relation to technological knowledge. Using Macdonald's research into the role of information in innovation, the paper identifies a number of factors besides isolation that constrain access to problem solving information; namely, organisation size, poor commercial relationships, absence of interpersonal contacts with experts and unrealistic expectations of newly qualified engineers. This analysis points to a broader set of challenges than is often accepted in the training of engineers in small island economies: that is firstly of the sufficiency of theoretical knowledge and secondly, information being widely available and easy to transport by communication technologies.*

Index Terms — context, engineering knowledge, development, problem solving, technology transfer

INTRODUCTION

A major factor in the successful globalisation of technology is the training of skilled practitioners. In the case of engineers and technicians, the goal is to promote equipment life and problem solving is an important element of this requirement. Perhaps most perplexing to observers is the limited impact formal education has had on the development of technological capability in developing countries [1]. While such issues are complex, one avenue for gaining a better understanding of this problem is to explore the impact geography and culture has on the process of skill development.

The paper therefore seeks to answer the question "what influence do physical and social contexts have on engineering knowledge development?". The paper responds to this question by firstly exploring the significance of this

question in relation to the literature on development, innovation and engineering knowledge development. The purpose of this review is to identify context as a worthy issue and to note a lack of attention to context in the dominant philosophical approach to engineering knowledge creation.

Drawing on the author's Masters research [2], the paper describes a number of examples in which context mediates the problem solving of a group of technical staff in a Pacific Island radio station. The concepts of "smallness" and "isolation" serve as two influential factors that limit opportunities for the technical staff to draw upon the expertise of other experienced practitioners, particularly equipment suppliers. Indeed, the main parameter analysed within the case study is the barriers that exist to information transfer. Macdonald's work on this subject is used to explore this issue in depth [3].

The paper concludes with a number of recommendations that can be applied directly to the case study as well as to situations that have similar characteristics. In terms of theoretical development, the paper supports those who wish to embed engineering knowledge development in geographic and social contexts. It is argued that such an approach enables a better understanding of the challenge of training engineering practitioners in isolated locations.

KNOWLEDGE DEVELOPMENT AND CONTEXT

The subject of context and its relationship to the development of technological knowledge is an issue that has been given some attention in the literature on development. One such example is drawn from the work of the economic historian, Rosenberg. He noted the existence of an inverse relationship between the distance a technology was transported from its place of development and the capabilities that were subsequently created [4]. Another example is from the economist Nelson. He described the problem of technology transfer in terms of the seller always possessing more information about the technology than could ever be contained in blue prints, operating instructions

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and the like [5]. In combination, the barriers to technological capability development from Rosenberg's and Nelson's perspective are related to distance and the "missing" component of knowledge.

The idea that distance should adversely affect the transfer of some knowledge forms and not others indicates to some commentators the two-part nature of technological knowledge. Referred to by Lamberton as a '...knowledge dichotomy...' [6] some definitions of technological knowledge have endeavoured to distinguish between its codified and tacit attributes. For example, Turpin et al. define codified knowledge as being characterised by its '...embodiment in technological artefacts, literature, technological processes and the like...' [7]. Tacit knowledge on the other hand, is '...embodied in people and their skills, technical know-how and experience in solving complex problems [8]. The difficulties associated with transporting tacit knowledge over distance are essentially ones concerning communication where barriers can be explained by the physical impediment of distance as well as the social barriers such as language or poor interpersonal relationships [9]. It is the latter area that has gained the attention of both development and innovation researchers who look to the nature of organisations for explanations of innovation performance [10].

If one looks to the dominant philosophy of engineering knowledge the codified and tacit aspects are not so much separated, as suggested by Lamberton above, but rather share a linear relationship. As Mitcham explains, such an approach is achieved by allying engineering knowledge development with scientific knowledge development [11]. Quoting Mario Bunge, Mitcham describes engineering as the '...scientific study of the artificial...or the field of knowledge concerned with designing artefacts and planning their realisation, operation, adjustment, maintenance and monitoring in the light of scientific knowledge...' [12]. Engineering practice is distinguished from knowledge on the basis that engineering practice is derived from, and is subservient to, theory. On this basis, one could conclude that there is little need to pay particular attention to context because the relationship between practice and theory is essentially a unidirectional one.

In relation to engineering training in developing countries, the question arises as to just what importance should be attached to the context as a determinate of knowledge development? To what extent can it be assumed that theoretical knowledge is self-sufficient when observations by development economists suggest otherwise? The Masters thesis undertaken by the author explores such questions in relation to the problem solving efforts of technical staff working for a Pacific Island radio station.

THE STUDY

The Masters research project from which this paper is drawn was essentially concerned with understanding how Pacific Island engineers solve problems within the context of "smallness" and "isolation". The themes of smallness and isolation are identified within Pacific Island literature as important concepts explaining why the economies and organisations of the Pacific are unlike those operating in industrialised countries [13]. Smallness implies insufficient numbers of experienced practitioners thereby limiting the opportunities that come from combining expertise to solve problems. Meanwhile, isolation refers to the distances that separate these engineers from overseas equipment distributors, identified earlier by Nelson as a singularly important source of information.

This study employed a qualitative case study methodology. As Yin explains, such a methodology is preferable for studying contemporary events and social situations that are comprised of complex relationships [14]. The case study group was the technical staff of a public broadcast radio station in a small Pacific Island country. The station employed 22 staff at the time of the research, four of whom were technical staff. Data gathering in the field consisted of participant observation, interviews and content analysis of documentary sources.

The analytical framework used in this study is taken from the work of Macdonald [16]. The purpose of an analytical framework is to make sense of the research data where social interaction and relationships are compared with a familiar concept or metaphor [15]. Macdonald is an innovation researcher who has developed expertise in analysing the role information plays in facilitating or constraining innovation with organisations. Macdonald's work was chosen for this study because it responds to the issues that are of dominant concern within this study – problem solving, the need for information external to the organisation and the unknown nature of the organisation and broader society. Macdonald is principally interested in the management of information that is related to experience and which is difficult to codify into theories, rules and the like – namely, tacit knowledge.

The organisation represents an important unit for analysis in this study because it frames most of the activities of the technical staff in both a physical sense and a social sense. The organisation and the influence it exerts over the technical staff is explored in two ways: firstly, how the organisation facilitates (or impedes) the problem solving efforts of its technical staff; and secondly, the kind of priorities the organisation sets for the technical staff and the consequent opportunities for problem solving.

The Organisation as Facilitator?

An information-based analysis implicates the radio station in hindering the problem solving activities of its technical staff. This stands in contrast to the more obvious initiatives the organisation employs to facilitate the problem solving of the technical staff, such as the provision of education and training as well as supplying them with equipment manuals and tools. The nature of this hindrance to problem solving relates to the poor access technical staff have to problem solving information from equipment suppliers.

What is the connection between supplier-vendor relationships and information transfer? Macdonald maintains that some form of transaction must accompany the transfer of information. The purpose of the transaction is to ensure that the supplier of information is compensated. The nature of the transaction may include the exchange of money, such as the payment of a wage or fee for the provision of expertise. On the other hand, compensation may be non-material. Examples of the latter kind of informal compensation may involve colleagues or friends who supply each other with information on the understanding that they may gain benefit from the recipient's expertise at some later time – that is, payment in kind. It is on this basis, Macdonald defines two kinds of information network – formal and informal information networks. While organisations may rely on formal information networks in contexts that are relatively stable, environments of change require quick and flexible means of obtaining problem solving information and this is where Macdonald has observed informal networks come mostly into play. Using this formal-informal dichotomy, it can be seen that the technical staff have difficulty in compensating equipment suppliers for information under either scenario.

Looking at formal information networks first, the prospect of future commercial benefit is one issue that may induce a supplier to provide information to the technical staff. Because of the limited finances of the radio station, it is perceived by the supplier as being of limited commercial benefit and this appears to dissuade the supplier from providing information. For example, the former technical coordinator of the regional broadcasting body, the Pacific Island Broadcasting Association (PIBA), revealed that he has had difficulty in acquiring the most basic of information from companies as revealed in this statement made to me.

'...I have money to spend but I have to beg them to send me prices...'

His requests for quotations are often left unanswered. Whether based on commercial acumen or ignorance, perceptions by equipment suppliers appear important in determining the access that these technical staff have to the problem solving information of the supplier.

Another example where institutional factors intervene on the formation of information sharing relationships is found in purchasing procedures. In this example, it can be seen that these factors affect the formation of less formal interpersonal relationships. At the time of the research, the radio station was required to channel all purchases from overseas suppliers (the bulk of equipment purchases) through a central purchasing authority of the government. Ostensibly, the organisation did not engage in any direct contact with the supplier beyond obtaining initial quotations. This was necessary because commercial transactions needed to be conducted across the legal jurisdictions of both the purchaser and the supplier and safeguards were required to ensure reciprocal obligations were met [17]. Delays of five weeks or more between initial ordering and final delivery were common. This had the effect of embarrassing the technical supervisor when he contacted these suppliers.

'...I hate calling up overseas suppliers to ask for prices when I can't promise them they will be paid quickly...'

When communication with the supplier does occur, it is often dominated by the need to establish whether documentation or payments have been received, if the goods have been despatched or their whereabouts in transit. It can be seen that the institutional relationships linking the organisation to the purchasing authority and, in turn, to the overseas equipment supplier, work against the establishment of viable networks of communication with suppliers.

Another issue that relates to the formation of informal information sharing relationships is equipment age. The supplier has little need for the problem solving information that these technicians may be able to provide because most of the "bugs" that seem to affect new equipment in the field have been fixed or the equipment in question is no longer crucial to the viability of the supplier's operations. Indeed, the age of some equipment within the radio station is such that suppliers no longer carry spare parts for these items.

In summary, these examples reveal that there are material and non-material costs involved in the acquisition of information. The technical staff find that they have insufficient "currency" in terms of limited financial capacity, authority and expertise to induce equipment suppliers into mutually beneficial information-sharing relationships. While competency to perform technical tasks is dependent on individual talent, a complementary institutional capacity to facilitate the formation of viable networks of communication with overseas experts is clearly lacking.

Factors that relate to the internal social dynamics of the organisation are also found to work against information transfer from suppliers. An incident involving the

breakdown of an auxiliary transmitter provides an example. Both management and the technical staff were under pressure because the transmitter was needed for the broadcast of parliament, a broadcast that many in the local community tune in to. The technical staff were required to continue working throughout the night to diagnose the fault and rectify it. They did so just hours before the scheduled broadcast of parliament was due to begin. Arguably, such a situation would have provided sufficient impetus for the technical staff to contact the equipment supplier, but this was not the case.

If one contends, as Macdonald does, that the most productive information networks flourish in the absence of organisational scrutiny, the actions of the technical staff in this example makes perfect sense. The kind of autonomy required to develop such networks is difficult to achieve in the radio station. This is because all international telephone calls are itemised on a monthly telephone bill and are then scrutinised by management and accounts staff. Add to this the observation that formal engineering qualifications give added standing to both individuals and their family, news of one requiring help to solve a difficult problem has the potential to undermine one's standing in the organisation and the broader community. While studies of engineering practitioners maintain that advice seeking between practitioners is considered necessary in resolving difficult problems [18], such behaviour represents another significant cost to the technical staff.

The Organisation as Priority Setter.

The second major influence that the radio station has over the problem solving of technical staff is revealed in the priorities it sets for them. These priorities generally reflect the demands of the broader community. Table I lists a number of problem solving situations that were observed during the time of the study. These problems have been organised into a matrix that identifies both the technical complexity of the problem [19] and the demands the organisation placed on the technical staff to have these faults fixed. The purpose of this table is to provide two examples that demonstrate that the learning of engineers and technicians is not solely determined by technical factors but is also influenced by social factors specific to that location.

Technical complexity does not solely define the actions of technical staff. Referring to Table I, the problems described in Situation 1 (the failure of the transmitter) and Situation 2 (the failure of the digital audio computer) were both technically complex problems. However, it was the demand from the organisation that directed the attention of the technical staff to the broadcast transmitter. As detailed earlier, both management and the technical staff were under

TABLE I
PROBLEM SOLVING MATRIX

Problem Solving Situation	Org. Demand	Technical Complexity	Attributes of Problem Solving Experience
(1) Parliamentary Broadcast Transmitter RF Drive Fault	High	High	Working under the pressure of a deadline; Difficulty in determining nature of fault; Required to work throughout the night.
(2) Digital Audio Computer	Low	High	Difficulty in determining nature of fault; No pressure from organisation; Fault left to languish as other priorities pursued.
(3) Audio Tape Recorder Signal to Noise Ratio (SNR)	Moderate	Moderate	Difficulty in maintaining specified levels of SNR due to aging equipment and lack of spare parts No significant outcry concerning excessive noise levels; Over time tape recorder specifications allowed to slip

considerable pressure to resolve this problem. Conversely, the failure of the digital audio computer did not represent a crisis because studio announcers were able to continue broadcasting using older equipment such as reel-to-reel tape recorders. So, it can be seen that organisational demand influenced the learning efforts of the technical staff. While knowledge had been gained about the transmitter, learning about the digital audio computer had not taken place.

Quantitative v qualitative measures of technical quality.

The example of the audio tape recorder, situation 3, shows another interesting interchange between organisational demand and engineering practice. It demonstrates that there may be tension between qualitative judgements of what constitute an adequate level of technical quality, and quantitative engineering measurements which are reflected in signal to noise ratio (SNR) measurements. SNR measurements noted by me during tape recorder alignment were of the order of 35 dB - well below minimum specified levels of 55dB below standard reference level [20]. Notably, these levels of SNR did not elicit any comment from program staff, or more generally, complaints from the general public. Without any significant demand, the only compulsion to maintain a SNR level of 55 dB appears as a zealous attachment to standards. In terms of the tension between what is considered acceptable quality in an engineering sense and in a social sense, the goals to which these engineers are being encouraged are heavily influenced by local perceptions of what constitutes acceptable quality.

The technical failure of a radio station is a very public occurrence, so the issues of concern to engineers are wider than humming machines and blinking lights. Indeed, the

satisfaction the technical staff gain from their work is partly derived from the positive impact their actions have on the broader community. Conversely, the learning opportunities from a fault of less significance to the organisation may be reduced such as the example of the audio tape recorder suggests or may even be lost in the case of the digital audio computer.

IMPLICATIONS OF THE STUDY

Having detailed a number of examples that establish a link between context and the problem solving efforts of engineering practitioners, the next task is to determine what significance the study has for engineering training in developing countries. As there are limitations to case study research, the implications are naturally most profound for those whose circumstances are most similar. In delivering training courses in a number of Pacific Island countries the author has observed many similarities between broadcasting organisations suggesting the paper has wider application.

In summary the lack of participation these engineers have in networks with other engineers outside the organisation is identified as a critically important issue. From an information-based perspective, access to sources of information, more particularly, the "hard to get" information derived from the experience of knowledgeable practitioners, is an important factor in the process of problem solving and hence knowledge development. In order to promote the formation of such information networks the analysis points to the need for more resources to be given to engineering practitioners. This is to enable them to better negotiate and command sources of information external to their organisation. Such resources include:

- **Purchasing.** The procedures leading to the procurement of goods, if designed to allow a more direct interchange between technical staff and equipment suppliers, could generate greater personal contact. If this leads to relationships of trust, productive information sharing relationships are more likely to follow. An initiative that would promote such an outcome is to give technical staff more authority to administer budgets and order equipment.
- **Private communication.** In addition to greater personal contact, the ability to engage in communication with equipment suppliers without scrutiny from the organisation is another factor of arguable benefit to the technical staff. In this respect, cheaper telecommunication services in the Pacific would promote interpersonal communication because there would be less need for the organisation to scrutinise communication costs. In a similar vein, more opportunities for overseas trips to equipment exhibitions would also promote the kind of personal contacts that are conducive to information sharing relationships.

- **Modern equipment.** The opportunity to work on modern equipment generates knowledge that has greater currency in engineering circles. Expertise in outmoded equipment is of limited significance to equipment suppliers as their current focus is naturally on current products and their associated problems. From this perspective, the well-meaning desire of some to supply developing countries with second-hand equipment is not a preferable strategy.

In essence, the above recommendations focus on the tacit dimensions of engineering knowledge development. The development of such knowledge has a strong social character attached to it. This paper maintains therefore that discrimination should be employed to distinguish between information based on the codified and tacit dimensions of engineering expertise. The case study seeks to broaden the scope of strategies that are designed to remedy the informational deficiencies of developing countries. While formal education and communication technologies are a necessary precursor to the transfer of information they are clearly not sufficient in themselves to ensure the transfer of problem solving information at critical times.

The findings of the paper also speak to situations where smallness and isolation may exist in western countries such as the United States, Australia and in Europe. The paper finds that the concept of isolation is not solely defined by distance so it is feasible that the experiences of the case study participants have relevance to small town businesses in developed countries. If this is the case, one could surmise that there is not so much a dichotomy of experience between practitioners in developing and developed countries but rather a continuum where the difference can be measured in degrees of access to problem solving information.

The last point the paper wishes to draw, and following from the previous point, is to question the suitability of engineering knowledge development strategies that are unable to effectively integrate physical and social context within their rationale. Does the engineering science philosophy expounded by Bunge serve the case study participants well? The case study demonstrates that there are many gaps in the knowledge possessed by the technical staff suggesting that, in a practical sense, engineering practice is not necessarily derived from theory. Bell and Pavitt go even further by describing the task of integrating global technologies into developing countries as an innovation process [21]. They maintain that many of the challenges are unique and describe the development of new knowledge as being the end product of problem solving.

One suggestion for engineering educators who have students working in isolated environments is to note the work of Staudenmaier [22]. In his study of engineering knowledge development, Staudenmaier observes that there

are many gaps in understanding the way technological artefacts work [23]. For him, theoretical knowledge is akin to a language that allows practitioners to better communicate about problematic areas of equipment function in the field [24]. Such an emphasis on communication and community in engineering education would serve the interests of all engineering practitioners who must deal with the local uncertainties of equipment and machines, as well as the environments they work in.

CONCLUSION

The paper set out to better understand the effect contextual factors have on the development of engineering knowledge in developing countries. The case study of a small and isolated radio station revealed a number of ways that both physical and social context can influence the problem solving endeavours of its technical staff. The manner in which these contextual features interceded on problem solving was firstly noted in the difficulties of communicating with overseas experts, which in turn placed a constraint on the transfer of problem solving information. Secondly, the influence the organisation had in determining the priorities to which the technical staff worked revealed that the organisation influenced the learning opportunities available to them. The paper suggests that greater attention to context may result in better learning outcomes for engineering practitioners who are faced with similar constraints of smallness and isolation. In a broader sense, the paper maps out further research directions in relation to promoting engineering expertise development in isolated locations. There is a need to find ways to better embed the practice of engineering in differing physical and social contexts.

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