Applying an Engineering HCI Framework to Telemedical Research: a Successful Case-study

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Abstract. This paper reports a case-study, in which an engineering HCI framework is applied to an example of telemedical research to establish how it might be advanced. The case-study is considered a success. All the concepts in the research are classified by the framework. Additional concepts from the framework are shown to be relevant to advancing the research. Such applications are considered to contribute to researchers building on each other's work and so better to support HCI discipline progress.

*Keywords***.** Engineering, HCI framework, Validation, Design knowledge.

1. Introduction

Human-Computer Interaction (HCI) researchers have been criticised for not building on each other's work. Newman (1994) claimed that only 30 percent of HCI research enhanced modelling techniques, solutions, and design tools, as against 90 percent for engineering more generally. The remainder of HCI research described 'radical solutions' (not derived from solutions of the same problem) and 'experience and/or heuristics' (gained from studies of radical solutions). Elsewhere, Long (1996) claims that poor HCI progress resides partly in the failure of research to validate its design knowledge.

Engineering HCI frameworks better specify the relations between research and the design of human-computer interactions (frameworks for: the HCI discipline (Long and Dowell, 1989); the HCI general design problem (Dowell and Long, 1998); and HCI knowledge validation (Long, 1996). Their application indicates the contribution of research to the design of human-computer interactions. In this way, advance of research can be assessed and what remains to be done identified. The frameworks thus support the advance of work and the validation of HCI knowledge, so meeting the criticisms of Newman and Long. This paper illustrates the use of such frameworks by applying them to research by the second author into video technology and medical consultation.

We must define what constitutes success and failure for this application, and the scope of its conclusions. First, scope depends on the research. Stork, et al., (1995) suggest the dimensions are: definition, complexity and accessibility. The use of audio-video links, for telemedical consultation, is: implicitly defined, simple and accessible. Thus, if the application is successful, we claim the framework to be useful for other similar work. The research is implicitly defined – there were no explicit goals or criteria for its success. It is simple, because the design space is small. It is accessible, because a researcher was available to provide required details.

So, what are the criteria for a successful case-study? It is easier to think about the criteria for failure. The case-study is unsuccessful, if there are concepts, or relations between them, in the research that cannot be classified by the HCI framework. The framework could not then be used to advance the work. Similarly, where there are concepts or relations in the framework, that have no corresponding concept or relation in the research, we must be able to argue the absence is a failing.

2. Telemedical Consultation

A description follows. All ('technical') concepts are highlighted and numbered (on first citation).

2.1. Summary of research

The **research** (1) is that of **telemedical consultation** (2). **Field studies** (3) were carried out in 1996. An **audio-visual link** (4) connected **medical specialists** (5) at one location with a **GP** (6) or **nurse practitioner** (7) in a **treatment room** (8) at another. In general, there was a **patient** (9) in the room, to whom the **consultant** (10) talked, at the same time as the GP or nurse practitioner. The sites had different facilities to send video images. Two sites had **portable cameras** (11) for sending images of the problem (eg, a wound). One site had **X-ray facilities** (12) for sharing images.

The study involved **interviews** (13), but also some **observation** (14) and **video analysis** (15). The aim was to understand the **problems** (16) and **advantages** (17) of using this **equipment** (18) for this **work** (19). The full **method** (20) and **results** (21) appear in Watts and Monk (1998). These results comprise a **work description** (22) as a sequence eg, switching on, examination and radiology, making contact. The text elaborates the **goals** (23) of the sequences as task characteristics. "The consultant wants to know the patient's history and patient's view of the problem." The problem is elaborated. "Consultation is mainly about talking". The technological problems of providing multi-party sound and the alternatives are discussed. Each task characteristic is followed by design **implications** (24).

2.2. Discipline framework
The highlighted concepts of Figure 1 present a general discipline framework (Long and Dowell, 1989). It specifies the relations between a discipline's research, practice and general problem. Research knowledge supports research practices, which acquire and validate practice knowledge, which supports practice practices, addressing the general problem, having a particular scope. This framework is now used informally to structure a 'neutral' discipline description of the telemedical consultation research.

2.3. Research knowledge
This knowledge supports the acquisition of design knowledge.

2.6. Practice practices
These practices apply the design knowledge in **system development** (37). The research involved no such application. It might, however, be the next logical step, involving writing **guidelines** (38) for **purchasing** (39) and setting up equipment. The guidelines might be refined by **iterative testing** (40) with GPs and other users.

2.7. General problem
The general problem is system development as the purchasing and setting up of audio-visual links.

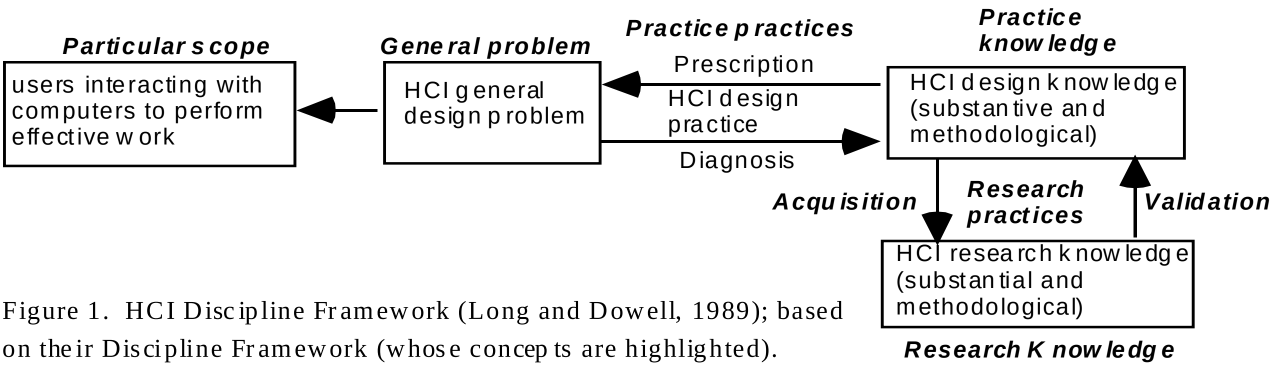

Figure 1. HCI Discipline Framework (Long and Dowell, 1989); based on their Discipline Framework (whose concepts are highlighted).

The researchers used **ideas** (25) in the field studies, derived from their knowledge of the field. Ideas about the use of **shared artefacts** (26), as **communicative devices** (27), led them to expect problems when views at the two ends of a link differed. Ideas from **task analysis** (28) led them to enquire about the work process. Research knowledge about interviews in situ with equipment at hand for prompts, makes it easier for **users** (29) to explain problems. This **knowledge** (30) is difficult to make explicit.

2.4. Research practices
These practices apply research knowledge to acquire design knowledge. Sixteen people were interviewed. Consultations were viewed and videotaped. This information was assembled to reason about the effects of the **communication facilities** (31) on consultation. To achieve this aim, a tabular representation, a **Comms (communications) Usage Diagram** (32) (CUD), was invented. It applies research knowledge, building on task analysis, to divide the work into parts, identified with advantages or disadvantages. The latter generally correspond to CSCW **issues** (33). These practices have a **scope of application** (34).

2.5. Practice knowledge
This knowledge is acquired by research and supports design. Watts and Monk identified six issues for telemedical consultation links to **consider** (35). "Issue 1: High quality multi-party sound is a primary **requirement"** (36); and "Issue 4: Parties at each end of the link need to have the same image of the problem".

2.8. Particular scope
The particular scope is system development as purchasing and setting up audio-visual links for medical consultation. The description of the research is now complete. The concepts appear in Table 1 (Column 2).

3. HCI Discipline Framework

Figure 1 presents the HCI discipline framework of Long and Dowell (1989). The framework is applied in the case-study. The concepts of the framework are highlighted here, as earlier. HCI **research** (1 R) comprises **knowledge** (1.1 K) (**substantive** (1.1.1 S) and **methodological** (1.1.2 M)) and **practices** (1.2 P) (**acquisition** (1.2.1 A) and **validation** (1.2.2 V)). Research supports HCI **design** (2 D), which also comprises **knowledge** (2.1 K) (**substantive** (2.1.1 S) and **methodological** (2.1.2 M)) and **practices** (2.2 P) (**diagnosis** (2.2.1 D) and **prescription** (2.2.2 P)). Design addresses the **HCI design problem** (3 DP), which is **general** (3.1 G), but which has a **particular scope** (3.2 PS) of **users** (3.2.1 U) interacting with **computers** (3.2.2 C) to perform **effective** (3.2.4 E) **work** (3.2.3 W). Table 1 presents the telemedical research concepts, informally organised, following the framework.

Table 1 and Figure 1 suggest: first, all research concepts and their relations can be informally classified by the framework. No concepts or relations then are beyond advance. Second, although the research claims to acquire HCI knowledge as: results (21); implications (24), more research is needed to advance this knowledge, such that it supports design (as system development (37); guidelines (38)).

Table 1. Concepts used to describe the Telemedical Consultation research, informally organised following the HCI Discipline Framework of Long and Dowell (1989) (Figure 1).

HCI Discipline Framework Concepts	**Telemedical Consultation Research Concepts**
1 HCI Research (R)	research (1)
1.1 Knowledge (K)	telemedical consultation (2)
1.1.1 Substantive (S)	work description (22); ideas (25); knowledge (30); comms usage diagram (32)
1.1.2 Methodological (M)	method (20); task analysis (28); scope of application (34)
1.2 Practices (P)	field study (3)
1.2.1 Acquisition (A)	interview (13); observation (14); video analysis (15)
1.2.2 Validation (V)	
2 HCI Design (D)	
2.1 Knowledge (K)	
2.1.1 Substantive (S)	results (21); implication (24); issues (33); (guidelines)* (38)
2.1.2 Methodological (M)	consider (35); (iterative testing)* (40)
2.2 Practices (P)	(system development)* (37)
2.2.1 Diagnosis (D)	problem (16); advantages (17)
2.2.2 Prescription (Pr)	requirement (36); (purchasing)* (39)
3 HCI Design Problem (DP)	
3.1 General (G)	
3.2 Particular scope (PS)	
3.2.1 Users (U)	medical specialist (5); GP (6); nurse practitioner (7); patient (9); consultant (10); users (29)
3.2.2 Computers (C)	audio-visual link (4); treatment room (8); portable cameras (11); xray facilities (12); equipment (18); shared artefacts (26); communicative devices (27); communication facilities (31)
3.2.3 Work (W)	work (19); goals (of work) (23)
3.2.4 Effectiveness (E)	problem (16); advantages (17) *not used in the research

Third, with no explicit reference to an HCI discipline framework, there are only implicit relations between discipline-level aspects of the research: between HCI design knowledge as: results (21); implications (24) and HCI design practices as: problems (16); requirement (36). There are only implicit relations between HCI design knowledge and practices, and the HCI particular scope as: medical specialist (8); audio-visual link (4).

The HCI discipline framework specifies additional, relevant concepts and more explicit relations and so supports better advance. HCI design knowledge as substantive and methodological, together specify HCI design practices, as diagnosis and prescription. HCI knowledge and practices together specify the HCI general design problem as users interacting with computers to perform effective work. As an example, diagnosis (2.2.1 D) in the framework is a design practice identifying poor performance of the worksystem. Such was the aim of the interviews (13) and what defines a problem (16) in the comms usage diagram (32) analysis. The concept of diagnosis (2.2.1 D) (and indeed prescription (2.2.2 P)) could be used to advance the research by making this objective explicit. The problem (16) in the comms usage diagram (32) needs to identify the performance attribute and its desired performance (work 3.2.3 W; effectiveness 3.2.4 E). The relations between users (3.2.1 U), computers (3.2.2 C), work (3.2.3 W) and effectiveness (3.2.4 E) would better advance the research.

4. HCI General Design Problem Framework

Figure 2 presents the HCI general design problem framework of Dowell and Long (1998). It specifies the relations between HCI design problems and solutions, as its particular scope. The framework is applied here. The concepts of the framework are highlighted as earlier.

The framework's particular scope comprises: **work** (1 W), carried out by an **interactive worksystem** (2 IWS) to achieve **goals** (3 G) at some level of **performance** (4 P). The **domain of application** (1.1 D) of a worksystem is the work performed. It comprises one or more **objects** (1.1.1 O), constituted of **attributes** (1.1.2 A), which have **values** (1.1.3 V). Goals (decomposed into **sub-goals** (3.1 SG), express required

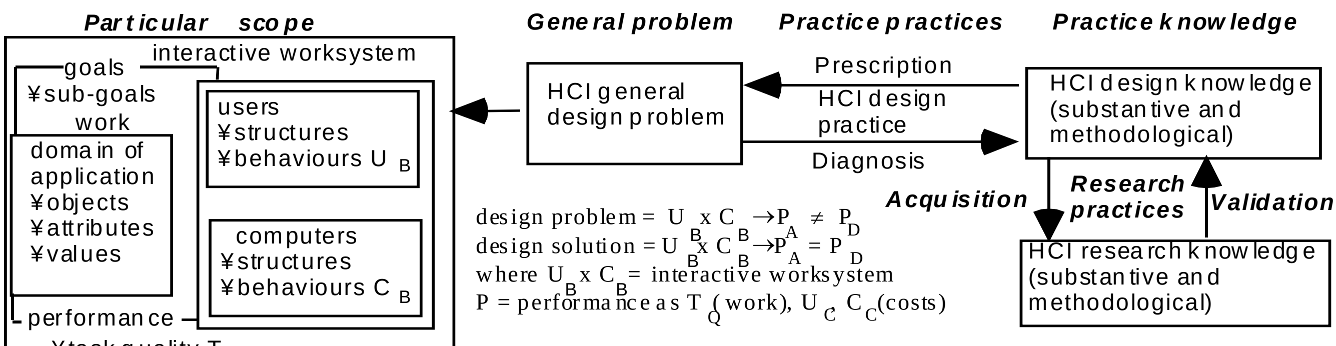

Figure 2. HCI General Design Problem Framework, (Dowell and Long 1998); based on their HCI Discipline Framework (Figure 1).

Table 2. Concepts used to describe the Telemedical Consultation research, informally organised following the HCI General Design Problem Framework of Dowell and Long (1998) (Figure 2).

HCI General Design Problem Framework Concepts	**Telemedical Consultation Research Concepts**
1 Work (W)	work (19)
1.1 Domain of Application (D)	telemedical consultation (2)
1.1.1 Objects (O)	
1.1.2 Attributes (A)	
1.1.3 Values (V)	
2 Interactive Worksystem (IWS)	
2.1 Users (U)	medical specialists (5); GP (6); nurse practitioner (7); patient (9); consultant (10); work description (22); users (29)
2.1.1 Behaviours (U_B)	
2.1.2 Structures (U_S)	
2.2 Computers (C)	audio-visual link (4); treatment room (8); portable cameras (11); xray facilities (12); equipment (18); shared artefacts (26); communicative devices (27); communication facilities (31)
2.2.1 Behaviours (C_B)	
2.2.2 Structures (C_S)	
3 Goals (G)	
3.1 Sub-goals (SG)	goals (of work) (23)
4 Performance (P)	advantages (17)
4.1 Task quality (T_Q)	
4.2 Worksystem Costs (WS_C)	
4.2.1 User Costs (U_C)	
4.2.2 Computer Costs (C_C)	
5 Design Problem (DP)	problems (16); issues (33); requirement (36)
5.1 $U_B \times C_B \rightarrow P_A \neq P_D$	
6 Design Solution (DS)	implications (24)
6.1 $U_B \times C_B \rightarrow P_A = P_D$	

changes in values of these attributes. A domain is distinct from, and delimits, a worksystem, which comprises two separate, but interacting, subsystems of **user behaviours** (2.1.1 U_B) and **computer behaviours** (2.2.1 C_B). These behaviours are supported by mutually exclusive **user structures** (2.1.2 U_S) and **computer structures** (2.2.2 C_S) and the behaviours are executed to perform effective work. Effectiveness is expressed as **performance** (4 P), how well a worksystem achieves its goals, **task quality** (4.1 T_Q) and **worksystem costs** (4.2 WS_C) that are incurred in so doing. Costs are incurred by both users – **user costs** (4.2.1 U_C) and by computers – **computer costs** (4.2.2 C_C). A **design problem** (5 DP) exists, when **actual performance** (5.1 P_A) does not equal **desired performance** (5.1 PD) (U_B x $C_B \rightarrow P_A \neq P_D$). A **design solution** (6 DS) exists, when actual performance equals desired performance (6.1 U_B x $C_B \rightarrow P_A = P_D$).

Table 2 presents the telemedical concepts, (Table 1), informally organised following the HCI general design problem framework (Figure 2). Table 2 and Figure 2 suggest: first, all the concepts and their relations, associated with the research, are informally classified by the framework. Thus, no concepts or relations are beyond advance. Second, few concepts are used to describe the work (19) - telemedical consultation (2), other than as users' behaviours, switching on. Third, only one concept is used to describe performance – advantages (17). Last, although research concepts relate to the framework concepts of design problem (5 DP), as problems (16); issues (33) and of design solutions (6 DS), as implications (24), there are no explicit concept relations or concept decompositions.

The HCI general design problem framework specifies: the concepts of work (1 W), performance (4 P), and design problem (5 DP) and design solution (6 DS); the relations between them; the interactive worksystem (2 IWS) and worksystem costs (4.2 WS_C) and their decomposition; and work (1 W) as a domain of application (1.1 D), expressed as objects (1.1.1 O), attributes (1.1.2 A) and values (1.1.2 V). The framework would thus support better advance by providing additional, relevant concepts and their relations. To pursue the earlier illustration, the problem (16) specified in the comms usage diagram (32) could identify the performance attributes of task quality (4.1 T_Q), how well the medical consultation is performed and the user costs (4.2.1 U_C), the workload of the medical specialists (5), GPs (6), incurred in performing the task that well. Such relations would provide more explicit support for the concepts of problems (16), issues (33), and remains to be done.

5. HCI Knowledge Validation Framework

The HCI knowledge validation framework, proposed by Long (1996), presumes the HCI discipline framework (Figure 1) and the general design problem framework (Figure 2). The framework specifies the status of relations within the particular scope of the HCI general design problem and within HCI design knowledge. The framework is applied here. Highlighting is as earlier.

In the framework, (Table 3), the **HCI design problem** (1 DP) is: **conceptualised** (1.1 C); **operationalised** (1.2 O); **tested** (1.3 T); and **generalised** (1.4 G) to support the acquisition and validation of **HCI design knowledge** (2 DK). This design knowledge in turn is: **conceptualised** (2.1 C); **operationalised** (2.2 O); **tested** (2.3 T); and **generalised** (2.4 G) to support the formulation of HCI design solutions to HCI design problems.

Table 3 presents the telemedical concepts (Table 1), informally organised following the HCI knowledge validation framework. Table 3 suggests: first, all the concepts and their relations, associated with design knowledge validation, are informally classified by the framework. Thus, no concepts or relations are beyond advance. Second, the HCI design problem concepts (1 DP) are only conceptualised as problems (16); issues (33) as concerns users (29), equipment (18) and work (19). The concepts are not operationalised, tested or generalised.

Third, the design knowledge concepts (2 DK) are only conceptualised as results (21), implications (24). The concepts are not operationalised, tested or generalised. Indeed, HCI design knowledge as guidelines (38), system development (37) were not conceptualised other than as 'the next logical step'. Fourth, the HCI design problem (1 DP) concepts as problems (16), issues (33) are not related to the HCI design knowledge concepts (2 DK) as results (21), implications (24). Last, neither the design problem nor the design knowledge concepts are explicitly specified.

The HCI validation framework specifies both the HCI design problem (1 DP) and design knowledge (2 DK) as conceptualisation, but also, operationalisation, test and generalisation. The framework would thus support better advance by providing additional, concepts and their relations. To pursue the earlier illustration, the problem (16) specified in the comms usage diagram (32) could be operationalised with respect to the relevant issues (30) or design implications (24), for example, 'high-quality, multi-party sound is a primary requirement (36) in telemedical consultation' (2). Operationalisation of the HCI design problem and knowledge would support validation of the latter with respect to the former and so advance the research. Such research remains to be done.

6. Advancing Telemedical Consultation Research

Application of the HCI framework, comprising discipline, general design problem, and knowledge validation, indicates that all the telemedical concepts and their relations (Table 1) can be informally classified. Thus, no concepts/relations are beyond advance. The main areas for advance are: design knowledge within the discipline framework; work, performance, design problem/solution, within the general design problem framework; and operationalisation, test and generalisation, within the knowledge validation framework. Within all frameworks, the research concepts and relations are implicit. Indeed, the general picture is of a craft (or craft-like) discipline, with informal and implicit knowledge and practices (Long and Dowell, 1989). It appears to be an engineering rather than a scientific one, since the research aims to acquire design knowledge. However, the research presumes a relation between understanding, as per science, and design, as if one precedes the other ("The objective was to understand the problems and advantages of using this sort of equipment for this sort of work.") This aim of understanding may account for the absence of design knowledge application and validation. The HCI framework suggests the telemedical consultation research could be advanced both in its own implicit craft-like terms and in more explicit engineering terms.

6.1. Implicit, craft-like advance

First, as concerns HCI, design knowledge, as results (21), implications (24) needs to be moved centre-stage to support a direct relationship between the research and the design problem of problems (16) and advantages (17). The research would be advanced, if results (21), implications (24), could be shown to obviate problems (16) and accrue advantages (17), during system development (37)/ purchasing (39) of audio-visual links for use by medical specialists (5). The research would be advanced, if it used the design knowledge to address the design problem.

Second, as concerns the HCI design problem, the research would be advanced, if its scope were extended to include: a more complete description of the work of telemedical consultation (19), and especially what aspects can be enhanced by different audio-visual link (4) designs; a distinction

Table 3. Concepts used to describe the Telemedical Consultation research, informally organised following the HCI Knowledge Validation Framework of Long (1996).

HCI Knowledge Validation Framework Concepts	**Telemedical Consultation Research Concepts**
1 HCI Design Problem (DP)	problems (16); issues (33); requirement (36)
1.1 conceptualised (C)	medical specialists (5); GP (6); nurse practitioner (7); patient (9); consultant (10); users (29); audio-visual link (4); treatment room (8); portable cameras (11); xray facilities (12); equipment (18); shared artefacts (26); communicative devices (27); communication facilities (31)
1.2 operationalised (O)	
1.3 tested (T)	
1.4 generalised (G)	
2 HCI Design Knowledge (DK)	
2.1 conceptualised (C)	results (21); implications (24); issues (33); consider (35); (system development)*(37); (guidelines)*(38); (iterative testing)*(40);
2.2 operationalised (O)	
2.3 tested (T)	
2.4 generalised (G)	*not used in the research

between how well the consultation is conducted (problems (16); advantages (17)), and the efforts to conduct the work that well (problems (16); advantages (17)); what goals relate the work (19) to its quality and the effort required; and last how design problems as problems (16) relate to design solutions as advantages (17).

Last, as concerns HCI knowledge validation, the research would be advanced, if its design knowledge as results (21), implications (24), were expressed as guidelines (38) and iterative testing (39), and so conceptualised, operationalised, tested and generalised, that is validated for design. The research recognises these ways forward, in its own craft-like terms, as 'the next logical step'. What the framework adds, however, is how the elements of the HCI discipline, general design problem and knowledge validation frameworks might be used to organise and to integrate the implicit research concepts and their relations.

6.2. Explicit, engineering advance

Craft-like advance could be carried out by the two researchers. Their personal experience could be carried forward from present to future research. Advance could also be carried out by others sharing those experiences by example (craft-like practice). But how might the research be advanced by others not so exposed?

First, because the relationship of research (1), results (21) and problems (16) is not explicit, an HCI discipline framework is required to advance the research, which better specified them as HCI research (1 R), HCI design (2 D) and HCI design problem (3 DP) (Table 1 and Figure 1). Second, because problems (16) and advantages (17) are not explicit, an HCI general design problem framework is required to advance the research, which better specified them as performance (4 P), constituted of task quality (4.1 T_Q) and worksystem costs (4.2 WS_C), constituted of user costs (4.2.1 U_C) and computer costs (4.2.2 C_C) (Table 2 and Figure 2). Last, because the specification of users (29) and results (21) is not explicit, an HCI knowledge validation framework is required to advance the research, which better specified them in terms of HCI design problem (1 DP) and design knowledge (2 DK) as conceptualised (1.1 and 2.1 C), operationalised (1.2 and 2.2 O), tested (1.3 and 2.3 T) and generalised (1.4 and 2.4 G) (Table 3). The framework would help ensure that advanced design knowledge is more effective at supporting a design solution (6 DS)(6.1 $U_B \times C_B \rightarrow P_A = P_D$) corresponding to a design problem (5 DP) (5.1 $U_B \times C_B \rightarrow P_A \neq P_D$) (Table 2). This research advance would be more explicit than that supported by implicit craft-like practice.

7. Case-Study Discussion and Conclusion

In general, the case-study can be considered successful (or not unsuccessful – see Introduction), inasmuch as the earlier requirements have been met. First, all the concepts in the telemedical research, have been informally classified by the HCI framework. Second, where framework concepts have no corresponding research concepts, the case has been made (for most, if not all – space precludes all) that adding them would be of value by identifying what research remains to be done.

One problem is matching the level of descriptions of the research and the HCI framework. The research could always be re-described at a lower level. Also, not all concepts of the framework have been used (see glossary, Dowell and Long, 1998). The case-study is, nevertheless, considered successful, because the HCI framework supported the research assessment.

As concerns the case-study scope, the research continues to appear: implicitly defined, relatively simple and accessible. The success of the case-study suggests the HCI framework shows promise for being useful to consider similar research. Future applications, however, should also include less implicitly defined, less simple and less accessible research as more demanding tests.

Finally, consider the criticisms of Newman and Long (earlier), that HCI researchers have failed to build on each other's work and to validate design knowledge. The telemedical research did build on the work of others, for example, task analysis (25), (CSCW) issues (20). However, this work did not constitute in Newman's terms 'solutions of the same problem'. Indeed, the research would seem to be rather an instance of 'experience and/or heuristics' (gained from a study of a radical solution, that is, the use of audio-visual links to improve medical consultation). Craft-like advance would not be expected to change this state of affairs. However, applications of the HCI framework, with its better specified HCI design problem and design solution, would be expected to support 'solutions of the same problem' by the use of 'modelling techniques, solutions and design tools', because the same problem would be known to be the same. This design knowledge would thus be validated and so contribute to Long's requirement for better HCI progress. The application of the HCI framework to the telemedical research has indicated how the advance of its design knowledge might better contribute to that progress.

8. References

Dowell, J., & Long, J. (1998). Conception of the cognitive engineering design problem. *Ergonomics, 41(2),* 126-139.

Long, J. (1996). Specifying relations between research and the design of human-computer interactions. *Int. Jnl. of Human-Computer Studies, 44 (6),* 875-920.

Long, J., & Dowell, J. (1989). Conceptions for the discipline of HCI: craft, applied science & engineering. In *Proc. BCS HCI SIG Conference* (pp. 9-32).

Newman, W. (1994). A preliminary analysis of the products of HCI research, using pro forma abstracts. In *Proc. CHI '94* (pp. 278-284).

Stork, A., Middlemass, J., & Long, J. (1995). Applying a structured method for usability engineering to domestic energy management user requirements: a successful case study. In *Proc. HCI '95* (pp. 367-385).

Watts, L.A., & Monk, A.F. (1998). Reasoning about tasks, activity and technology to support collaboration. *Ergonomics, 41(11),* 1583-1606.