REF2021

Institution: Liverpool Hope University (LHU)

Unit of Assessment: B11: Computer Science and Informatics (CS&I)

Title of case study: Transforming enterprise collaborative decision-making for distributed knowledge-workers and underprivileged adolescents

Period when the underpinning research was undertaken: Sept 2007- December 2020

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Prof. A.K. Nagar	Professor and Head; IDS Lead.	Since Sept. 2001; & IDS Lead: 2005 - 2018.
Dr. H. Tawfik	Associate Professor	April 2003 – July 2015.
Dr. O. Anya	Research Assistant	June 2007– August 2012.

Period when the claimed impact occurred: January 2014 - December 2020.

Is this case study continued from a case study submitted in 2014? No.

1. Summary of the impact (indicative maximum 100 words)

The development of online collaboration tools that enable workers to share knowledge across geographical boundaries and integrate diverse Web-based information sources to support collaborative decision-making in business, healthcare and elsewhere has been one of the most important advancements in enterprise work in the last 20 years. Our research on context-aware e-Collaborative and e-Health Decision Support has made pivotal contributions to this advancement, and its impact, significance and reach, have extended globally. The research has:

a. been integrated into online collaboration and enterprise work support applications developed at IBM Research Almaden, Silicon Valley, USA resulting in a patented product, which is being used by hundreds of businesses globally.
b. led to development and deployment of new models of collaborative care management of adolescents with behavioural and psychological issues in India to support vulnerable people; and
c. informed the IT strategy and policy development of the UAE Ministry of Health on e-health collaboration.

2. Underpinning research (indicative maximum 500 words)

Advances in information technology created a "flat world" of networked sociality and generated remarkable shifts in the way people deploy social networks and Web-based information for personal use. However, in the enterprise setting, particularly in the business and healthcare sectors, it remained a huge challenge until recently to enable online collaboration and leverage Web-based information for collaborative problem-solving and decision-support across geographical and organisational boundaries. The research of the Intelligent and Distributed Systems Research (IDS) Group focused on this challenge by designing, developing, and publishing in mainstream outlets new theoretical frameworks, conceptual models, tools and processes to facilitate adaptive collaborative problem-solving and context-aware cross-boundary decision-making with enterprise workers and healthcare professionals in mind.

Under the IDS group, Nagar (expert in Mathematical Sciences) and Tawfik (expert in Artificial Intelligence) jointly co-supervised a British funded research project **[G1]** and the doctoral work of Anya, who has expertise in Human-Computer Interaction and Social Informatics and was the Research Assistant employed on this co-supervised IDS group project. Our research approach started with in-depth understanding of enterprise and healthcare work practices using social science methodologies, including ethnography and user-centred design. Findings were integrated with computer science techniques, including artificial intelligence approaches and mathematical

simulation and modelling, in order to design and prototype complex new work environments for collaborative decision support for e-work and e-health. Today, our research has played a major role in the design and development of enterprise work support systems and online collaboration tools and guidelines that have made it possible for many companies globally to collaborate easily and securely across geographical, organisational, and national boundaries, get answers to questions quickly, and speed up decision-making in a way that leads to better solutions to complex business and healthcare problems (patent **[P1])**. The research that underpins the impacts claimed, are described below clustered in four research topics (**RT1-RT4**) and mapped to references and the specific impacts.

[RT1] Adaptive and Collaborative Knowledge-based Work Environments: For this research we employed participatory research methods to work and co-design with local small and medium scale enterprises in North-West England with a strong focus on businesses seeking to adopt collaboration systems to improve productivity. The study **[R2]** laid out a set of guidelines and theoretical foundations for the design of workplace and online collaboration technologies, and demonstrated its application by developing a knowledge transfer framework that enabled technology transfer, as part of the research itself, to the small and medium scale enterprises we worked with. The study developed a model of collaborative work support for e-work, known as **e-Workbench**. The solution was delivered as a part of the Hope Solutions package – a business outreach program of Liverpool Hope University.

[RT2] Practice-centred e-Health System Design for Cross-Boundary Clinical Decision Support: We worked with over two dozen clinical professionals across three different geographical areas – the UK, UAE, and Nigeria in order to understand how local work practices in various hospitals, healthcare organisations and clinical contexts across regional and geographical divides affect the way clinical decisions are made in those places **[R1]**. The study identified three factors that define and characterise contexts of clinical practice in various geographically disparate work settings, and revealed that an awareness of a clinician's work practices at three levels (ontological, stereotypical and situated practices) plays a crucial role in adapting knowledge for cross-boundary decision support. Based on the findings, we explored the role of the concept of 'practice as a design' requirement for building clinical decision support tools for collaborative decision making among clinical professionals working across organisational, national, and geographical boundaries. From this we developed a model of e-health decision support for facilitating sharing of knowledge and supporting clinical decision-making among doctors working in-cross boundary contexts **[R3, R4]**.

[RT3] Context-Aware Multimedia Information System for e-Health Decision Support: We developed a model of a knowledge-rich and intelligent context-aware system for supporting patients' information management and medical decision making in an open and dynamic ubiquitous medical environment. The system allows effective collaborative healthcare service delivery by virtual teams. Overall, the research **[R4]** contributed to a rich understanding of the technological and social system enablers of the data-driven knowledge economy of the 21st century, including the design of systems and tools for open innovation and seamless collaboration in distributed work settings. This British Council funded project **[G1]** was jointly executed with the British University in Dubai, UAE, and delivered solutions and frameworks for advancing technology in the area of context-aware collaborative decision support in e-health.

[RT4] YUVA: An e-Health Model for Dealing with Psychological Issues of Adolescents: Based on our practice-based context-awareness framework for ubiquitous e-health **[R5]**, we leveraged Nagar's joint work with colleagues from Indian Institute of Technology (IIT) Roorkee

(North India) and Christ University Bangalore (Delhi Campus in North India), to develop a model of collaborative decision support to enable distributed collaboration and decision making amongst distributed non-governmental (NGO) workers/volunteers (who were also part of the research in addition to being users) in North India. The model named "YUVA" (or adult) **[R5]** was based on RWD (responsive web development) and provided an easy and adaptable electronic platform for dealing with various health/psychological (physical & mental) issues of adolescents by integrating diverse online information covering healthcare, education and governmental policies.

3. References to the research (indicative maximum of six references)

Underpinning Research: has been published in international, high-quality, mainstream, peer-reviewed outlets (such as the *IEEE Transaction on IT in Biomedicine*; *Journal of Computational Science*) and receives citations from across the research area; was funded; and led to a patent.

[R1]. H. Tawfik, O. Anya and A.K. Nagar, Understanding Clinical Work Practices for Cross-boundary Decision Support in e-Health, *IEEE Transactions on Information Technology in Biomedicine*, Vol. 16, No. 4, pp. 530-41, 2012.

[R2]. O. Anya, A.K. Nagar, and H. Tawfik, Building Adaptive Systems for Collaborative E-Work: The e-Workbench Approach, *International Journal of Intelligent Decision Technologies, Special Issue on Knowledge-based Environments and Services in Human-Computer Interaction*, IOS Press, Vol. 5 No. 1, pp. 83-100, 2011.

[R3]. H. Tawfik and O. Anya, Evaluating Practice-centred Awareness in Clinical Decision Support Systems for Telehealth, *Telematics and Informatics*, Elsevier, Vol. 32, No. 3, pp. 486-503, 2015.

[R4]. O. Anya and H. Tawfik, Designing for practice-based context-awareness in ubiquitous e-health environments, *Computers & Electrical Engineering*, Vol. 61, pp. 312-326, 2017.

[R5]. S. Srivastava, M. Pant and A.K. Nagar, YUVA: An e-health model for dealing with psychological issues of adolescents, *Journal of Computational Science*, Vol. 21, pp. 150-163, 2017.

Grant:

[G1]. H. Tawfik, S. Amin, A.K. Nagar, and K. Shaalan, Context-Aware Multimedia Information System for e-Health Decision Support, PMI2 Connect Research Co-Operation Award (Gulf States) of the UK Government (Sponsorship ID: PMI – RCGS286), 2009-2011. Amount: £35025.

Patent:

[P1]. O. Anya, R. Moore, H. Nezhad, Migrating enterprise workflows for processing on a crowdsourcing platform, US Patent App. 15/071,098, No: US20170269971A1, 2017.

4. Details of the impact (indicative maximum 750 words)

Our underpinning research (**RT1-RT4**) has three major routes to the four distinct and material impacts **[I1 to I4]** being claimed, namely: **(i)** adoption of our outputs by IBM (2013–2017), which in turn influenced the development of collaborative decision-support products for their enterprise clients, and a patent invention **[P1]**; **(ii)** our work advising UAE Health Systems (2014-2020); and **(iii)** supporting NGOs in India making a difference to the lives of underprivileged adolescents and their families (2017-2020).

[I1]. Impact on the design and engineering of enterprise collaboration services [RT1-RT3; S1]: From Jan 2013 to June 2017, Anya was recruited to the postdoctoral researcher programme of the IBM Research, widely considered to be one of the most prestigious corporate research laboratories in the world. As noted by the Vice President (VP) and Lab Director of IBM Almaden in **[S1]**, "*through the postdoctoral program, IBM Research has built and nurtured strong industry-academic relationships with universities … and created inventions that shape our world. It is this*

kind of relationship that IBM Research developed with Liverpool Hope University, UK." This relationship between IDS and IBM Research enabled us to integrate our research into actual product developments and patent inventions that shaped how businesses globally collaborate across national, geographical and organisational boundaries **[S1]**. Our research informed and influenced research priorities of IBM's Work Design Innovation and Smarter Work Initiative, resulting in new models and guidelines for the design and development of enterprise work systems, including a US patent on **enterprise crowdwork**, and thereby influenced opportunities for furthering the research agenda of IBM's Smarter Work Initiative. Additionally, our work raised other system developers' awareness working in this field about the critical role of work practice as a design requirement for developing enterprise work and collaborative decision support systems.

The VP of IBM Almaden further adds in **[S1]** that our research has "*contributed to and influenced strongly the work of the Work Design Innovation team at IBM Research.*" This contribution:

- resulted in "*new models and guidelines for the design and development of enterprise work systems and online collaboration tools, used by many businesses globally today to enhance workplace collaboration and collaborative decision making across disparate locations.*"
- "*contributed positively to the design of future work systems—tools and processes that facilitate and support collaborative work—using Artificial Intelligence software*", and
- made "*an indirect contribution to one of IBM's patents, …, led by Dr Anya.*"

The VP concludes that the real "*impact of Professor Nagar's research group … derives from the group's unique approach that starts with people's practices and interests, and then integrates sophisticated mathematical and computer science principles and techniques.*" The VP further adds that our research has brought such a unique combination of "*dual abilities in computer and social science to further the research agenda of IBM's Smarter Work Initiative*".

[I2]. Impact on enterprise professionals using IBM products reaching out to Businesses [RT1-RT3; S1]: Our key research output, called '**e-Workbench framework**', was integrated into human-centred crowdsourcing enterprise work applications implemented by IBM's Work Design Innovation group to develop online collaboration tools used by hundreds of enterprise businesses in different parts of the world to enable workplace collaboration among individuals across geographical and organisational boundaries. The VP and Lab Director of IBM Almaden further commented in **[S1]:** "*In particular, the research has inspired IBM's Work Design Innovation at IBM Research Lab, Almaden*" and the system is "*used by over a dozen enterprise organizations and cloud providers.*"

[I3]. Informing and influencing UAE Health System's Strategy [RT1-RT3; S2]: We conducted a series of participatory design sessions to gain in-depth understanding of the unmet needs of healthcare professionals, and consequently co-designed a knowledge transfer framework that led to an increase in the adoption of collaborative e-health technologies. One significant example of this was the work with Health practitioners in the UAE which was jointly executed with the British University in Dubai, who were 'co-creators' of the research outcomes. This resulted in the UAE Health System benefiting from the new insights as the then Acting Undersecretary for Support Services and Director of IT testified in **[S2]** that our work ("*a timely intervention*" **[S2]**):

"*contributed to informing, influencing, improving, and impacting the eHealth infrastructure, which in turn benefits millions of people regionally and globally, in the following ways:*

- *Wider government initiatives to e-enable services in the UAE which has been an ambitions initiative over the last five years;*

- *The preparations and basis for the launch of the national health strategy seeing through to 2020 and beyond;*
- *Gap-analysis that enabled common ways to exchange information leading to fast, secure, reliable, and personalised health care support.*"

This was possible as we were able to introduce alternative views on the use of evidence in clinical decision-making in e-health that combines ethnomethodology and intelligent system design in a way that accommodates work practice as a fundamental part of how clinicians work in the real-world. We demonstrated the perceived usefulness and adoption of the systems and e-health applications developed by our research for actual UAE users (comprising physicians and other healthcare professionals).

[I4]. YUVA e-health platform facilitating work of NGOs working with underprivileged adolescents [RT4; S3; S4]: Our research has contributed an ICT framework and a new e-healthcare model for human-centred health informatics and collaborative management of behavioural and psychological issues, which has been deployed as a Responsive Web Application and used by over ten Indian NGOs for the provision of care to adolescents with behavioural and psychological issues across North India **[S3, S4]**. The YUVA e-health model has increased collaboration among NGO volunteers and helped them to develop more empathy towards adolescents they care for in the organisation by better understanding the various psychological issues that the adolescents go through; particularly amongst youths of underprivileged families who have an annual income of less than USD $100 – mostly labourers, rickshaw-pullers, house maids etc **[S4]**. The President of an NGO called *Amrit Varsha* (whose slogan is '*Sab padho, khelo aur badho*' (in Hindi), which translates to 'every child should learn, play and grow in every sphere of life', comments that our work has enabled them to develop "*a structured approach to our work with the adolescents, their families, and the volunteers who work with our organization.*" This has:

- "*Resulted in new frameworks for the transformation of human experience at work and the development of human-centred resources and web-based materials/App in a simple way for families and children of underprivileged sections of the society.*
- *Helped in changing the perception and mindsets of children and their parents towards the mental health issues and it helped in enhancing their curiosity towards the usage of technology;*
- *Enhanced our work practices and influenced the way we work giving us an altogether new direction that we are keen to continue to develop in the future as well as the technology and science advances.*" **[S3]**.

The President further observed that their organisation is happy that "*through YUVA, we were able to reach out to a large section of underprivileged sections of the society in the Ghaziabad/Noida regions of Uttar Pradesh (UP).*" Based on their positive experience, this NGO recommended YUVA framework to four other NGOs, volunteers, and their beneficiaries, also working with underprivileged adolescents utilising the YUVA framework; e.g. as in **[S4]**, a beneficiary wrote that YUVA helped "*children deal with different problems*" and helping "*become better persons in life*".

5. Sources to corroborate the impact (indicative maximum of 10 references)

[S1]. Letter of endorsement from Vice President of IBM Research Centre, Almaden, Silicon Valley, CA, USA and IBM-University Global Partnership.

[S2]. Letter from the Former Acting Undersecretary for Support Services and Director of IT.

[S3]. Testimonial from President of Indian NGO – Amrit Varsha.

[S4]. Testimonial letters from the volunteers working for the NGOs (some in the Hindi language).