The intertwined threads of work

by James Trevelyan
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It is astonishing at the start of the 21st century that we still only have a tiny handful of systematically researched accounts of engineering practice beyond a few glamorous aspects of design. What do engineers and technologists really do in their work? How does engineering really happen?

To find out, my colleagues and I have completed more than 120 extensive interviews since 2004, mainly in Australia but also in other countries, followed by field observations and rigorous qualitative analysis. I noticed engineers doing lots of coordination in which hard technical knowledge is inextricably bound up with soft skills such as understanding human behaviour. The latter is time-consuming and most engineers don't see it as engineering work. After countless phone calls chasing up suppliers, contractors, colleagues and clients, an engineer would often say something like "now I can get down to some real engineering work at last". Yet this coordination work is essential to get good results. Here's a sample answer to the question of what a typical day or working week involves: "Wednesdays were our meeting day on site. The rest would be just random madness, really."

Technical coordination is working with, and influencing other people so they willingly and conscientiously perform some necessary work to an agreed schedule. It mostly seems to happen without any formal authority, seeking willing cooperation instead. It may be simply asking a colleague to search for data or persuading a client to sign off on design specifications or chasing up a contractor to supply some component samples.

Technical coordination usually starts with negotiation on what has to be done and when.

Most of the effort goes into following up, often face to face, to see if the work is turning out as expected and spotting misunderstandings early enough for corrections to be made in time. Time constraints often force compromises, and choosing where and how to compromise relies on accurately predicting the technical, social and commercial consequences. The choice of appropriate follow-up intervals varies and it is hard to discern any systematic approaches.

At the end, careful checking is needed to make sure no further work or rectification is required.

Our research is revealing that engineering practice consists of two intertwined threads. The first is largely intellectual: understanding social needs, and then conceiving solutions and predicting how well they will work. Prediction has to be as accurate as possible, on technical, commercial, environmental, safety and timescale issues. Predictions provide answers to questions like "How much will it cost? When will it fail? How long will it take to build? How safe will it be? How will it affect atmospheric emissions?" Prediction relies heavily on engineering science – about the only part taught extensively at universities.

The other thread is practical: delivering solutions that match the predictions. This has to be done almost completely through the hands of other people: artisans, labourers, contractors and suppliers. Compromises in delivery are negotiated through awareness of the predicted consequences, and performance prediction is always qualified by practical experience.

Engineering relies on distributed cognition, unwritten tacit knowledge and hidden skills

Contrary to popular perceptions of a precise science-based discipline, our research is showing that both threads of engineering rely mainly on distributed cognition, unwritten tacit knowledge and hidden skills. Engineering is a complex social and technical system, often only partly understood by its own participants.

This model emerges in the form of several aspects of engineering practice, each of which in turn can be subdivided into finer levels of detail. Many aspects are seldom mentioned, even in industry training courses. They are:

- managing self and personal career development
- coordination, working with other people
- engineering processes, project and operations management
- financial processes
- procurement, buying products or services
- human resource development, training
- business development or marketing, selling products or services
- technical work, creating new concepts, problem solving, programming
- technical reviews, checking, testing and problem diagnosis
- hands-on technical work, construction or repairs.

The big surprise in our research was that technical coordination seems to be the most prominent aspect of engineering practice. Next came formal engineering processes like project management, followed by checks such as inspection, testing, checking and review. Creative technical work, design and calculations were fourth, followed by procurement, business development, and personal career development.

The pattern emerging from our research is that engineering is as much a social discipline as a technical one. Whether it is writing software for a mobile phone or planning more efficient maintenance schedules, engineering work has little intrinsic value until it has passed through the hands of many other people. Yet, this reality seems to be almost invisible in our current engineering education curricula.

Many engineers tell us that they find technical coordination difficult. Sometimes they talk in terms of “seeking alignment”. Yet in practice they will often assume that other people will cooperate just because “it is their job” and when that doesn’t happen, they may point to “an attitude problem”.

The importance of soft skills in engineering has been widely acknowledged. Yet soft skills are often taught separately from technical issues. Our research suggests that soft skills have to be combined with technical expertise to master the difficulties in effective technical coordination – a core component of engineering practice.

Professor James Trevelyan is the discipline chair for mechatronics at the University of Western Australia. Further information on the project can be accessed at http://www.mech.uwa.edu.au/jpt/pes.html. Readers are invited to contribute their own experiences and stories on technical coordination, either by email to James.Trevelyan@uwa.edu.au, or by post to the University of Western Australia 6009.