The Application of the Repertory Grid Interview Method for Improving the Identification and Understanding of Competencies Required for Engineering Practice

Mahmud, M N[1]
Doctoral Student
Institute for Manufacturing, University of Cambridge
Cambridge, UK

Ridgman, T W
University Lecturer
Institute for Manufacturing, University of Cambridge
Cambridge, UK

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INTRODUCTION

Educating engineers through outcome-based education requires the identification of competencies required for engineering practice. One of the ways in which such competencies can be identified is by engaging with practising engineers through interviews. During interviews, engineers are asked to describe competencies required for various aspects of engineering practice. However, there are at least two main limitations in such interviews. First, practising engineers often find it difficult to articulately describe and explain part of competencies that are implicit [1]. Second, interviewers often find it difficult to accurately interpret words and phrases used for competency descriptions [2]. Interview methods that can improve the identification and understanding of competencies required have therefore been called for.

This paper describes an interview method that can help interviewers in identifying part of competencies that are implicit, and in interpreting words and phrases used by interviewees. We adopt, adapt and apply the Repertory Grid Technique (RGT) method for interviewing practising engineers. It is found that such approach can facilitate the elicitation of competencies that are implicit to the interviewees. It can also help in accessing personal meanings of words and phrases used by them.

This paper begins by discussing the explicit, implicit and tacit aspects of engineering practice, and the use of interviews for gathering the knowledge about the first two aspects. Then, the two limitations in using interviews for gathering such knowledge are discussed. After that, the RGT interview method is described with an illustrative example of how the interview process addresses the two difficulties.

[1] Mahmud MN

Finally, we highlight our own reflection on the utility of the interview technique for understanding aspects of engineering practice.

1 KNOWLEDGE ABOUT ENGINEERING PRACTICE

Knowledge about work practices, such as engineering practice, generally exists in at least three forms: the explicit, implicit and tacit forms [1, 3]. The explicit form can be readily articulated in words and/or represented in visuals by practitioners for others to understand it [4, 5]. On the other hand, the implicit form cannot be readily articulated by practitioners. According to Bennet and Bennet [4], the implicit form consists of "*knowledge stored in memory of which the individual is not immediately aware, but may be pulled up when triggered*". Whereas, the tacit form consists of "*knowledge that cannot be pulled up in words, a knowing of what decision to make or how to do something that cannot be clearly voiced in a manner such that another person can extract and re-create that knowledge (understanding, meaning, etc.)*"[p.407]

Since it is possible to articulate and codify the explicit and implicit forms of knowledge about practice, researchers who seek to understand engineering practice through interviews must be able to gather and document at least the explicit and implicit forms.

Although the explicit form can be readily expressed in words, interviewers must ensure that they accurately interpret words used by their interviewees according to meanings that are intended by the latter. Without accurate interpretations, it can be difficult for interviewers to rule out other possible competing or alternative interpretations, and thereby reducing the confirmability of data (i.e. free of researcher bias). Therefore, interviewers must be able to show that interviewees' have explicitly and unambiguously provided the personal meanings of words that they have used.

However, accessing personal meanings of words that can mean differently to different individuals, and facilitating the recall of implicit knowledge remains difficult in interviews with practising engineers [1]. These two difficulties are described in the next section.

1.1 Difficulty in accessing personal meanings

It is common for practising engineers to use technical terminologies and disciplinary jargons in describing aspects of engineering practice [6]. This can cause difficulties for interviewers who are unfamiliar with jargons. Often, such difficulties are so obvious that interviewers feel the need to seek for the meanings directly from their interviewees. However, the need to seek for meanings may not be so obvious when interviewees use commonly used words. Problems tend to arise when the commonly used words carry different meanings for different individuals. Interviewers may be less aware that the meanings they ascribe to those words can be different from the personal meanings intended by their interviewees. Consequently, the former may not seek clarification, but may assume prematurely that both parties share common understanding. As a result, their interview session tend to be exposed to the risk of interviewer bias.

For example, the use of the word 'independent' by an interviewee who suggests the importance of the 'ability to work independently' can expose an interview session to bias in interpretation. This is because the word 'independent' can be interpreted in at least three different ways. It is unclear whether the interviewee refers to the ability to work individually instead of in group, or the ability to carry out work with minimal supervision, or the ability to work without following guidelines and manuals, or some other idiosyncratic meanings that the interviewer may not be aware of.

Such bias may impact on the validity of research results. This is especially the case when data analysis involves the categorisation of data based solely on similarity in words rather than on similarity in their meanings as intended by interviewees.

In view of the above, a more systematic method is needed to help interviewers in accessing and interpreting personal meanings of words and phrases used in competency descriptions.

1.2 Difficulty in facilitating the recall of implicit aspects of engineering practice

Research on engineering practice has recognised that a large part of aspects of engineering practice are implicit, and that they are often difficult to gather through interviews with practising engineers [1]. James Trevelyan for example, observed that the social aspects of engineering practice, such as coordinating the work of others, are implicit for many practising engineers; they tend not to mention these aspects during interviews even though these are found to be the dominant part of their work practice [1, 5]. Compared to solitary technical work, which tend to be explicitly mentioned during interviews, social aspects of engineering work tend to be 'forgotten'. This is because many practising engineers who participated in Trevelyan's studies reported that social aspects of their work are either uninteresting to be mentioned, or are diluting what they perceived should be purely technical. Some of these implicit aspects can only be gathered through repeatedly probing the interviewees, or through direct observation and follow-up interviews [7]. This costs valuable time and effort in data collection.

The difficulty in getting interviewees to mention the implicit aspects of their work arises also due to the way in which these aspects are practised at work. Bjorklund [8] finds that implicit knowledge about work practice*"...is also used in an automatic way and is therefore difficult to elicit by introspection*"[p.3]. He contends that "*If we want to elicit this ... we can't use ordinary interview techniques. The information is not stored in a verbal form and the interviewee maybe doesn't even know it's there and is controlling his decisions and actions*"[p.4].

In view of the difficulty in gathering the implicit aspects of engineering practice during interview, we need an interview technique that can help interviewers in eliciting them.

In the next section, the Repertory Grid Technique (RGT) method of interviewing is introduced. Additionally, how the method address the two difficulties are also discussed.

2 THE REPERTORY GRID TECHNIQUE (RGT)

The RGT method of interviewing is underpinned by the Personal Construct Theory (PCT). The theory, emerged in 1950s within the Personal Construct Psychology, a branch of psychology field of studies. PCT states that individuals actively construe their experiences by making sense of the events, activities, objects, and people they encounter in life. Their construing influences the meanings they ascribe to words that they use to describe their life experiences [9]. Consequently, when prompted with interview questions, they are more likely to respond using words that have personal meanings. Because individuals are likely to differ in their life experiences, there is a possibility that interviewers and interviewees interpret similar words differently, as exemplified by our earlier example of multiple interpretations of the word 'independent.' The RGT emphasises that personal meanings of words need to be ascertained during interviews in order to avoid misinterpretation.

The process for conducting the RGT interview is described based on the guidelines provided by Devi Jankowicz [10]. It will be shown how the two difficulties discussed in the previous section are addressed in the process.

2.1 Process and Procedure

The interview process begins by agreeing on the topic of discussion between the interviewer and the interviewee. This is followed by identifying items that make up the topic. These items are called 'elements' in RGT terminology. An example of a type of elements that make up the topic of engineering practice is a list of engineering tasks undertaken by individual interviewees. Typically, interviewers would ask interviewees to specify elements that they can think of so that only elements that are perceived to be personally relevant to the latter are used. However, in some applications elements supplied by interviewers have also been used.

After that, the interviewer uses the elements to get verbal responses from the interviewee. Typically, such responses contains terms, concepts and phrases which are collectively called ‘construct’ in RGT’s terminology. A construct represents how interviewee think about an element. For example in thinking about an engineering task, such as designing a device, an interview may suggest ‘planning ahead’ as a relevant construct.

Constructs can be elicited using elements in at least three different ways: the triadic, the dyadic and monadic way [10]. The triadic way uses three randomly selected elements from the list of elements, and ask the interviewee to compare and contrast them.

Focusing on the three randomly selected elements, interviewees are then asked to identify two elements which they think are similar in some way, and identify one element that they think are dissimilar from the other two in some way. Following this identification, interviewers ask two questions to interviewees “in what way are these two similar?”, and “in what way does the third one differ from the other two?”. In order to ensure that the comparison between elements are aligned with the research objective, interviewers can provide a qualifying statement to interviewees. For example, if the research objective is to identify competencies required for engineering practices, interviewers can orientate the interviewee to think of the similarities and differences between three engineering tasks by saying “how are these two similar in terms of competencies they require?”, and “how does the third one differ from the other two in terms of competencies it requires?”.

Whenever the dyadic method is used, comparing and contrasting is done between two randomly selected elements. In this case, interviewers ask two different questions: “in what way are the two items similar?”, and “in what way are they different?”. On the other hand, the monadic method develops construct using one element at a time without making any comparison with other elements. In this case, the interviewer asks “how do you see this item in terms of ......”.

The RGT interview method also assumes, based on the PCT, that a construct has two extreme points, called ‘poles’. For example, an interviewee may think of an engineering task as requiring an engineer to ‘work independently’ instead of to ‘work under close supervision’. In this case ‘work independently’ and ‘work under close supervision’ represent two extreme poles of a construct. PCT also assumes that individuals tend to place things at either extreme or at some point in between the two extremes. The first pole that the interviewee identifies is known as the ‘Explicit Pole’ which signifies that individuals tend to state it explicitly in communication. The other pole is known as the ‘Implicit Pole’ which signifies that individual tend to hold it implicitly in their mind instead.

RGT requires interviewer to identify the ‘implicit poles’ because doing so would convey the personal meanings of words used for the corresponding ‘explicit poles’. For example, an interviewee might say that his task requires him to ‘work independently’. Unless he/she also says that his work does not for example, require ‘working under close supervision’, an interviewer may or may not interpret it in the exact same way because ‘working independently’ may (and quite commonly also) mean ‘working individually’ instead of ‘working in a team’.

Thus, the development of a construct necessarily consists of two steps: identifying the explicit pole, and then getting interviewees to identify the corresponding implicit pole. This elicitation processes is repeated using different set of elements until both parties feel that the interview session has adequately cover the topic.

Finally, all elements are rated against each of the constructs in order to understand how interviewees define the elements more precisely (i.e. where do they place each of the elements along the two extreme poles). Ratings are usually used to quantitatively indicate the placement. For example, an element of engineering task called ‘testing a device’ can be rated using a number between 1 to 5, with 1 represents for example, ‘working independently’ and 5 represents ‘working in team’.

Ratings are useful for analysing similarities or differences between two or more elements, or between two or more constructs. In this way, similar elements or constructs can be grouped into a common category based on their similarities in rating. In this way, a large number of elements or constructs can be systematically reduced to a smaller number of categories or themes.

3 ILLUSTRATIVE EXAMPLE

In this section, we illustrate our application of RGT interview method to one interview. This illustrative example forms part of an exploratory research that seeks to identify the capabilities (i.e. knowledge, skills, and abilities) required for early career engineers in emerging industries. The interviewee is an Electronic Design Engineer, who has been working for three years in a start-up company that has a presence in the emerging Plastic Electronic industry in the UK.

3.1 Interview Data

The interview uses the monadic method to elicit constructs from a list of work tasks supplied by the interviewee. Table 1 shows part of the RGT interview data obtained from a one-hour interview.

Table 1. Sampled RGT interview data

Discussion Topic: Capabilities required for carrying out work tasks **Elements:** 10 different work tasks suggested by the interviewee	
Constructs: Capabilities	
Explicit Pole	**Implicit Pole**
Making informed predictions	Conducting trial-and- error
Planning ahead	Fixed to a design
Visualising the final product	Referring to existing designs
Seeking information through online search	Referring to experienced others
Converting requirements into real life applications	Not suggested
Using artistic imagination	Not being artistic
Being systematic at work	Not being systematic

The next section illustrates how some of the implicit poles in the right column of Table 1 have been useful for accessing personal meanings and for identifying the implicit aspects of capabilities.

3.2 Accessing personal meaning of constructs

First, we show how the RGT interview has helped in accessing the personal meaning of constructs, using an example of the explicit pole: 'making informed predictions' and its corresponding implicit pole: 'conducting trial-and-error'.

Making prediction is a common aspect of engineering practice that has appeared in literature on engineering practice in established industries (see for example, the work of Trevelyan [2]). Therefore, there is a tendency for an interviewer who has been informed by such literature to interpret the meaning of 'making prediction' as related to '*predict performance of solutions using modelling and simulation of proposed technical solutions and/or design'*, which requires engineers to *'…construct models and verifying model accuracy'*[p.17].

However, this is not an accurate interpretation of the interviewee's personal meaning of 'making prediction' which was made much clearer after he verbalised his implicit assumption (i.e. his contrast to it), which is 'conducting trial-and-error'. By making this contrast explicit, he emphasised the required capability to make informed prediction based on the underpinning knowledge of engineering sciences (e.g. physical and chemical properties, characteristics and behaviour of new electronic materials), so that costly endeavour in conducting trial-and-error could be avoided. This ‘making informed prediction’ based on theoretical knowledge (e.g. properties of materials) is somewhat different from ‘making prediction’ based on methodological knowledge (i.e. modelling and simulation). This example shows that the elicitation of the implicit pole helps the interviewer in gaining access to the personal meaning of the term, and thereby reducing the risk of interviewer’s bias.

Similarly, the interviewee was not thinking about ‘planning ahead’ in the common sense of developing plan for achieving certain predetermined objectives. Rather, he was referring to the incorporation of design flexibility instead of ‘getting fixed to a design’. According to him, this is important to allow for the possible customisation of the initial design due to the uncertainty in changes in market requirement as the new industry evolves.

However, the other two capabilities – ‘Visualising the final product’ and ‘Seeking information through online search’ – did not appear to be more precisely interpreted after the revelation of their corresponding implicit poles. Nevertheless, by revealing the implicit pole ‘Referring to existing design’, the interviewee had emphasised moreover, that many of the things developed by the company he works with are novel products, and therefore requires him to rely more on visualisation than on the improvisation of existing designs.

The other three capabilities however, show different results. The interviewee was not able to suggest any contrast for the capability of ‘converting user requirements into real life applications’. For the other two capabilities, the interviewee simply provided the negatives (i.e. simply by adding the word ‘not’ in front of the explicit pole), rather than suggested a contrasting capability. Nevertheless, in these three cases, the failure to register a contrasting capability or to arrive at one with the non-negative form (i.e. with the word ‘not’ in it), did not appear to end up with conflicting interpretation.

3.3 Facilitating the gathering of implicit aspects of engineering practice

Secondly, we illustrate how the RGT interview method can identify the ‘implicit pole’ of constructs that are related to engineering practice, as well as specifying their relevance to individual work tasks. The identification of the implicit pole of a construct only indicates potential capability not that it occurs in practice. The interviewee needs to explicitly indicate, through the rating process, whether or not the potential capability is required.

The rating process that we used involves assigning either the ‘Required’ or ‘Not Required’ indicators. At the end of the rating process, complete information on the requirement of each of the explicit and implicit capabilities for each of the tasks is available for subsequent analysis. We used a simple analysis that works out the percentage of tasks that require each of the capabilities (i.e. the number of tasks in which the capability is required divided by the total number of tasks). The results are shown in Table 2 below.

Table 2. Percentage applicability

Explicit Poles	%	**Implicit Poles**	**%**
Making informed predictions	100	Conducting trial-and-error	89
Planning ahead	78	Fixed to a design	44
Visualising the final product	89	Referring to existing design	78
Seeking information through online search	89	Referring to experienced others	100
Converting requirements into real life applications	44	Not suggested	-
Be artistic in using imagination	44	Not being artistic	-
Be systematic at work	100	Not being systematic	-

It can be deduced from Table 2 that some of the capabilities that were identified as the implicit poles are perceived to be required for most of the tasks. For example, ‘Referring to experienced others’ was considered as required for all tasks, despite of not being immediately suggested as an explicit pole for any of the tasks. In our interview, the interviewee explained, that although his first preference is for seeking information from data sources, he had realised that referring to experienced others are apparently frequently required especially in newly emerging areas where knowledge has yet to be codified in mainstream textbooks and information database. This implicit aspects have also been reported by others for example, Michael Eraut [3] who reported the prevalence of learning from others.

Similarly, the interview process also facilitated the awareness of the applicability of ‘conducting trial-and-error’, despite the earlier emphasis on the more explicit capability of ‘making informed prediction’ based on the underpinning knowledge of engineering sciences. The interviewee explained that while knowledge about the properties of conventional materials (e.g. ceramics) can easily be found for making informed predictions, he also had to work with the less conventional nano-materials (e.g. nano inks for printing electronic circuits), the knowledge of which was still incomplete, thus requiring the ability to conduct experiments. He also realised that although visualising the final form of plastic electronics products is obviously required in his work, such visualisation however, tend be informed by the existing design of equivalent products in conventional electronics, thus requiring the ability to refer to the existing designs. Nevertheless, the interview did reveal that the ability to work with a fixed design is less required than the ability to plan ahead by incorporating design flexibility.

3.4 Reflecting on our experience in applying the RGT

In terms of the impact of applying the RGT to the research outcomes, we found that the method is useful for gathering data on the required capabilities. In particular, the ability to access personal meanings of constructs has mitigated the risk of interviewer bias. Additionally, the rating process has helped to ascertain the requirement of the explicit and implicit capabilities for each of the tasks.

In terms of the process, during the elicitation of the required capabilities, it was found that the explicit poles appeared to be more easily elicited than the implicit ones. Also, it seems that not all explicit capabilities necessarily have their contrasting capabilities. Therefore, the reliance on the implicit poles for accessing the personal meaning of the constructs does not always appear to be applicable. Despite this, it does not appear that the personal meanings of the explicit capabilities were understood differently by the interviewer.

The interview process tends to be intensive in that it requires a great deal thinking to provide response to the prompts as well in indicating the applicability of the capabilities to the task. While this helps to gather more meaningful, rather than superficial, responses from the interviewee, it also often results in mental exhaustion for both the interviewee and the interviewer.

Last but not least, the identification of explicit and implicit capabilities required for each of the tasks helps to reveal the complexity of engineering practice in that most tasks require the interviewee not only to be able to combine many different capabilities, but also to be flexible in possessing some contrasting capabilities.

This application of RGT for identifying competencies required is limited by small samples of interviewees. Whereas this paper seeks only to illustrate the potential utility of the method, the assessment of the actual potential is a future work that requires more samples.

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