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Q Workshop: An Application of Q Methodology for Visualizing, Deliberating and Learning Contrasting Perspectives

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ABSTRACT

A value-centered approach to science, technology and society (STS) education illuminates the need of reflexive and relational learning through communication and public engagement. Visualization is a key to represent and compare mental models such as assumptions, background theories and value systems that tacitly shape our own understanding, interests and interactions. Yet conventional approaches including concept mapping and multi-criteria value elicitation methods often have little suggestion or implication as to how participants themselves can address and deliberate the incompatibility of their perceptions, preferences and perspectives. This study proposes Q workshop as a legitimate eliciting and deliberation technique that can be employed in pluralistic discourse, exploring systematic divergences of perspective by constructing the participant's self in a formative, emergent and contingent manner. For this it introduces Q mapping as a novel visualization tool for the hybridity of qualitative and quantitative methods derived from Q methodology. Q mapping is a two-factor solution that transforms the similarities in participants' individual Q scores into distances represented in two-dimensional space, for the sake of illustrating the relative positioning and partitioning of perspectives in a schematic figure. A case study on STS education for postgraduate students demonstrates that Q workshop can play a heuristic and abductive role in providing independent illumination of distinguishable perspectives and facilitating individual and collective learning among participants, suggesting a schematic two-dimensional basis for resolving the key differences.

KEYWORDS
Q methodology, reflexive learning, mental models, visualization, participatory works

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Introduction: Representation of Mental Models

Over the last forty years science education research has recognized that science should be placed in the context of how it affects technology and society. A recent movement of science, technology and society (STS) education deals sensibly with moral and ethical reasoning of socioscientific issues (Zeidler, Walker, Ackett, & Simmons, 2002; Zeidler, 2003; Sadler, 2004; Donnelly, 2004; Zeidler, Sadler, Simmons, & Howes, 2005). A value-centered approach (Pedretti & Nazir, 2011) reveals that learning socioscientific issues encourages people to actively reflect and examine the relevant connections between science and their own values and perspectives (Allchin, 1999; Driver, Newton, & Osborne, 2000; Kolstø, 2001, 2006; Bell & Lederman, 2003; Sadler, 2004; Sadler & Donnelly, 2006; Sadler, Barab & Scott, 2007; Zeidler, Sadler, Applebaum, & Callahan, 2009). Science communication studies have also begun to place more emphasis on understanding the multifaceted relationship between science and the variety of values, as well as the importance of reflective thinking and deliberation (Nisbet & Scheufele, 2009; Dietz, 2013). This illuminates the need of reflexive and relational learning through communication and engagement in science education by moving away from such labels as "experts" and "lay citizens" (Cuppen, 2012a; Chilvers & Kearnes, 2016). Reflexive learning concerns insights into the assumptions, background theories and value systems that tacitly shape our own understanding, interests and interactions (Felt & Wynne, 2007; Chilvers, 2013; Voß & Kemp, 2006) on the basis of double-loop learning (Argyris & Schön, 1978). Relational learning involves "learning about the independent integrity of others" (Felt & Wynne, 2007, p. 63).

Values are created and developed by frames (Nisbet, 2009), worldviews (Cobern, 1996; Lacey, 2009) or mental models (Bruine de Bruin & Bostrom, 2013) through which people interpret new information. One difficult challenge is how to represent mental models for communication, engagement and learning. A mental model is an internal conceptual representation that corresponds to the representation of the external structure (Gentner & Stevens, 1983). According to a less instructional but more theoretical and dynamic approach, a mental model continues to be enlarged and improved as new information is incorporated into it (Doyle & Ford, 1998; Greca & Moreira, 2000; Jones, Ross, Lynam, Perez, & Leitch, 2011). Representation of mental models can be accomplished by the externalization of information through visual models (Mnguni, 2014) and the form of this visualization affects the structure of mental models acquired during learning (Ramadas, 2009; Schnotz & Kürschner, 2008). Externalization of mental models is also a key in cooperative learning (Scardamalia & Bereiter, 1987). Cooperative learning is an instructional technique whereby people work together in small groups to improve their own and each other's learning (Cooper, 1995; Johnson & Johnson, 1999; Bowen, 2000). It has great effects on participants' learning when groups are focused on the individual learning of their members (Slavin, 1996). Reflexive learning then occurs at the collective level through shared mental models (Kim, 1993; Espejo, 1996), visualization of which can facilitate communication and consensus between participants (Swaab, Postmes, Neijens, Kiers, & Dumay, 2002).

Among the most common methods to represent mental models (Carley & Palmquist, 1992; Jonassen & Cho, 2008; Al-Diban & Ifenthaler, 2011) is concept or cognitive mapping (Novak, 1990). It is now widely applied as a graphical node-arc representation of the relationships among a collection of concepts that reflects some aspect of subjectivity, and is thought to support understanding, learning and decision-making (Lumpkin, 1999; Kolkman, Kok, & van der Veen, 2005; Hay, Kinchin, & Lygo-Baker, 2008; Daley & Torre, 2010). There are various ways to articulate mental models at the group level, with a link to the idea of a shared understanding (Kim, 2009; Scholz, Austermann, Kaldrack, & Pahl-Wostl, 2015). Whereas most methods focus on mental models and their changes within subjects, only a few compare mental models between subjects (Schaffernicht and Groesser, 2011). Cluster analysis can categorize and compare mental models as a metric (Mathieu, Heffner, Goodwin, Cannon-Bowers, & Salas, 2005), but it requires a great number of samples (large-N) to confirm its validity, which reduces its applicability for participatory practice in terms of sample size and representativeness. More applicable may be multiple criteria value elicitation methods for stakeholder analysis (Hermans & Thissen, 2009), including the analytic hierarchy process (AHP) (Lu, Lian & Lien, 2015) and multi-criteria mapping (MCM) (Stirling & Mayer, 2001; Burgess et al., 2007). These group-based practices aggregate different mental models at the collective level and/or compare them in an illustrative way but do not make sensible suggestions on how to regroup them beyond preset categorization of stakeholders. In addition, time-consuming nature of these approaches is seriously problematic for one-shot participatory practice to facilitate immediate communication and learning. To address such challenge, this study demonstrates 'Q workshop' applying Q methodology as a public engagement exercise to think about and learn different mental models.

Q Methodology

What is currently referred to as Q methodology was created over 80 years ago by William Stephenson. The methodology was named Q methodology to make a contrast with the conventional approach to the use of multivariate factor analysis in the study of psychological processes, which he labeled 'R methodology'. Among other stakeholder analyses, there are a variety of advantages to Q methodology. First, it excels at quantitatively identifying different frames shared by specific groups of stakeholders in participation, even when these are implicit. In other words, Q methodology deliberately pursues 'social representations' that are linked with a special way of acquiring and communicating knowledge (Watts & Stenner, 2005; Moscovici, 1981). Second, notwithstanding the prominence of quantitative procedure, Q methodology effectively combines the strengths of both qualitative and quantitative research traditions since it is designed to examine an individual's subjective experience that is typically passed over by other quantitative procedures (Brown, 1996; Stenner & Stainton Rogers, 2004). Third, Q methodology does not require any presupposition about the structure of research subject and participants, where other methodologies might find it difficult to avoid preconceived demographic and occupational notions. Fourth, it is more feasible because of the relatively few human, financial and time resource requirements and because it permits a considerable degree of flexibility in choosing subject items and participants. Stephenson's original ideas have recently gained in prominence in academia, where a number of researchers have pursued the implications and applicability of his ideas in communication (Giannoulis, Botetzagias & Skanavis, 2010), policy studies (Addams & Proops, 2000; Ockwell, 2008; Cairns, 2012; Cairns & Stirling, 2014), stakeholder engagement (Sleenhoff, Cuppen & Osseweijer, 2015; Cotton & Mahroos-Alsaiari, 2015) and other related areas (Dziopa & Ahern, 2011). Among a number of elicitation methods for identifying individual mental models, some observe that only Q methodology supports an analytically grounded grouping of mental models and provides the relative distribution of different mental models (Raadgever, Mostert, & Van de Giesen, 2008; Day, 2008). A couple of policy studies have so far attempted to facilitate mutual understanding and communication between participants using Q methodology (Cuppen, Breukers, Hisschemöller, & Bergsma, 2010; Cuppen, 2012b). There are relatively few studies in education research. All of these studies apply Q with an aim to systematically engage with and interpret participants' values, opinions and attitudes in relation to learning but not to facilitate their learning per se (Cothran & Ennis, 1998; Lecouteur & Delfabbro, 2001; Cross, 2005; Barker, 2008; Ramlo, McConnell, Duan, & Moore, 2008; Ramlo, 2012; Chen, Chen & Chen, 2015).

In Q methodology, a set of participants (P set) are usually selected as 'discursive representatives' (Dryzek & Niemeyer, 2008) in order to ensure that there is enough diversity among their perspectives in the group, and not necessarily to provide an accurate mirror of the population (Watts & Stenner, 2012, pp. 70-71). Individual participants conduct a rank-order procedure of a set of samples (Q samples). Samples are usually collected from a random collection of self-referable statements about something conceived for any situation or context. This 'concourse' of statements (Stephenson, 1978) can be operationalized as the complete population of statements made in or around the area at hand (Dryzek, 1990). The Q set is normally a set of statements that serve as a reasonable representation of the concourse. Given a risk of 'unstructured' samples that are under- or over-sampled and inadvertently introduce a bias of some kind into the final Q sample, theoretical structuring is a more systematic procedure often by using a cell structure as a heuristic device for selecting statements (McKeown & Thomas, 1988). Individual participants are then asked to sort Q samples according to a sorting grid in the form of a forced quasi-normal distribution (Q sort). In terms of the range of distribution (i.e. the width of the Q sort scale), the larger the number of statements, the wider the range of available scores should be. Taking a range of +5 to -5 as generally employed for the number of statements from 40 to 60 (Brown, 1980, p. 200), less than 40 statements for a Q set is often allowed to conduct Q sorting. The general shape of the distribution should vary in complexity, as should the uncertainty of the issues and the participants' knowledge and expertise.

After Q sorts are collected and correlated, factor analysis is performed to identify the underlying structure of relationships between the Q sorts. In doing so, firstly, it is necessary to decide the method of extracting 'factors', which represent the underlying dimensions that account for the original set of observed variables (i.e. Q sorts). The correlation of each variable and the factor is called 'factor loading' and this is the means of interpreting the role each variable plays in defining each factor. Accordingly, participants associated with higher loadings for a factor are the representatives of the factor. An important tool to have a more meaningful pattern of factor loadings is factor rotation, which generates heavy loadings of each Q sort on one factor and trivial loadings on the other. This is achieved by a process called rotation that can be conducted either according to mathematical criteria (e.g. varimax rotation) or by a visual procedure (i.e. judgmental rotation, or 'hand rotation'). Both methods are on a par and it is reasonable to employ one method according to the aim of the research (Brown, 1980, p. 238).

In participatory practice, once the factors are identified, the participants are broken down into groups according to their Q methodology factor. In order to explain and understand the different perspectives, each group usually begins with an analysis of the extreme poles of the Q factor array and then moves toward more neutral scoring statements. Through consideration of within-factor variation and comparisons with other factor arrays, it builds up a narrative, summarizing account of the factor (McKenzie, Braswell, Jelsma, & Naidoo, 2011).

Q Workshop

A considerable number of studies have demonstrated the utility of Q methodology for specific research aims, the support of stakeholder consensus, decision making and public policy (Durning & Brown, 2006; Brown, Durning & Selden, 2008), it being centered on the analysis of the resemblance between persons with regard to measures of agreement (Dijkstra & van Eijnatten, 2009). In participatory research, Q methodology has also been regarded as a practical tool to select participants for a stakeholder dialogue (Cuppen et al., 2010), as well as to identify changes in perspectives before and after the dialogue (Cuppen, 2012a). Yet a problem arises when researchers downplay elicitation of the partitioning and relative positioning of perspectives for reflexive and relational learning. Conventional applications of Q methodology remain a static and passive presentation of different (and possibly contentious) perspectives, which often have little suggestion or implication as to how participants themselves can address the incompatibility of these perspectives to communicate with and learn from each other. It is curious that while Stephenson (1967, 1969, 1978, 1986), among others, has insisted on the subjective and communicative functions of Q methodology, thus far little effort has been put into developing methods to improve participants' individual understanding and mutual communication and learning through Q methodology. As a remedy, Q workshop deliberately takes different steps in sampling participants and statements from standard Q applications and introduces a novel visualization tool in combination with R factor analysis.

P set

Strategic sampling as a standard way to recruit participants for Q methodological research may not be recommendable where researchers emphasize and attempt to facilitate interaction between participants in order to identify the differences in their perspectives, views and thoughts regarding social interaction including mutual understanding and learning, problem identification, issue framing, agenda setting, consensus building, and decision-making. As examined later, Q workshop can function more fully in heuristic and action-oriented participatory research, which necessarily entails a more opportunistic approach to participant sampling.

Q set

It is significant that in Q methodology participants propose, deliberate and arrange statements themselves, which goes beyond simple random sampling (and large sample size) or unstructured sampling. Instead of the conventional division between structured and unstructured sampling techniques, Yuichiro Takahashi (personal communication, January 27 & February 25, 2015) proposes three types of sampling for Q sets: theoretical, exploratory and deliberative. First, in 'theoretical sampling', which can often be observed in psychology, the investigator uses a set of theoretically established (and empirically confirmed) statements. Second, 'exploratory sampling' refers to the process in which the investigator assumes a set of statements based on literature review and expert interview and confirms the Q set reflecting individual participants' feedback on the relevance of statements. In a Q study, for example, researchers impose a Fisherian grid on statements selected by participants from the existing study (McKenzie et al., 2011).

Third, in the case of 'deliberative sampling', all the participants propose and deliberate statements at a gathering and complete a Q set. In the course of deliberation, which is usually facilitated by the investigator or a professional facilitator, some statements are separated, shortened, abstracted or incorporated together into single short statements to improve the clarity if there are any unclear, ambiguous, double barreled, or similar statements in meaning. These participatory approaches can avoid the risk of unstructured sampling that some opinions will be under- or oversampled and constructing a Q set that participants do not understand or know what the statements mean. They can also avoid the risk of structured sampling framed by the investigator's own values and interests. Deliberative sampling enables participants to digest the statements more quickly and smoothly and consequently shorten the time of Q sorting. Furthermore, such real-time collective sample collecting and editing through interaction and collaboration may provide the participants with a sense of ownership of all the statements and a sense of commitment to the completion of Q sorting and the analysis result. For instance, some Q studies conducted workshops to generate statements that express participants' perspectives (Mattson, Byrd, Rutherford, Brown, & Clark, 2006; Mattson, Clark, Byrd, Brown, & Robinson, 2011). In the sense that meaning is organized in relation to different configurations of the statements of a concourse (Stephenson, 1978), the shared process of constructing a concourse makes finalized statements communicable with all the participants as 'common knowledge' (Stephenson, 1982) where the connotation of a statement is at risk of being strongly influenced by the proposed participant's own voice and context.

Q sort

In deliberative sampling, which Q workshop normally adopts, participants are more familiar with individual statements because they can have common knowledge on the statements when proposed by other participants and confirmed by everyone at a workshop. It is inadvisable to take a much flatter distribution for the Q sorting grid since there is little information on participants' knowledge and perceptions in advance of the Q sorting. As the bottom line it is safe in most cases to take a shape more similar to the normal distribution.

Q factor analysis

In Q workshop as a real-time participatory appraisal, varimax rotation considerably saves time and effort to have analytical results with the help of dedicated computer software like PQMethod (Schmolck, 2011).

R factor analysis

In order to make the case visually illustrative for understanding, R factor analysis of Q sort data is applied as another quantitative analytical method. The distinction of R analysis and Q analysis is reviewed in great detail elsewhere (Burt & Stephenson, 1939; Stephenson, 1953; Brown, 1980; Durning, 1999) and entering this ongoing debate (Danielson, 2009; Brown, 2009; Kampen & Tamás, 2014; Brown, Danielson & van Excel, 2015; Tamás & Kampen, 2015) is clearly beyond the scope of this article, so suffice it to say here that R analysis is primarily concerned with attributes, whereas Q analysis is primarily concerned with objects. Unlike in the cases using Likert-type scale data (Martin & Steelman, 2004; Thompson et al., 2012), a fundamental problem of our combinative method is that Q sort scores are not independent each other and thereby R analysis is strongly affected by Q methodology. As prominent advocates of Q repeatedly warn when using Q and R in parallel (Stephenson, 1953, p. 15; Brown, Danielson, & van Exel, 2015), the use of R analysis should be regarded as a supplementary representation of the Q sort analysis results for externalization of mental models.

This study takes principal component analysis as a basic model to obtain factor solutions since our primary concern is extracting two factors that account for the maximum portion of the total variance. The factor rotation method after the extraction is the varimax method, which seems to give a clearer separation of the factors than other methods and which has proved very successful as an analytic approach to obtaining an orthogonal rotation of factors. Factor loadings by R factor analysis indicate the degree of correspondence between the variable and the factor, with higher loadings making the variable representative of the factor. It is generally applicable to define factor loadings of more than ±0.40 as practically important when the sample size is 100 or larger (Hair, Anderson, Tatham, & Black, 1998, p. 111). A more practical criterion we usually apply is to adopt statements with the highest 5 and lowest 5 loadings as the variable representative of the factor. Thus we have 4 sets of 5 statements for higher and lower factor loadings for Factor 1 and 2. The investigator then names each set by examining what these 5 statements represent or imply for the theme of Q sort. This is evidently subjective judgment and requires professional expertise, which can be biased by the investigator's own interest and concern. Mathematically speaking, it does not make sense to put names to both higher and lower factor loadings for the same factor because a set of statements for lower loadings should mean exactly the opposite to that for higher loadings. Thus, if we label "X" for a set of higher statements for a factor, a set of lower statements for the factor should be labeled "non-X". Statistically, however, the two-factor solution is the result of extracting statements into only two factors. This means that one factor can encompass many different sets of ideas, meanings and perspectives, which can allow us to have two labels at each end for better interpretation of the factor.

Unlike with Q methodology, the sample size seriously matters in the R factor analysis. As a general rule, the minimum sample size will have at least five times as many observations as there are variables to be analyzed, and a more acceptable size would have a ten-to-one ratio (Hair et al., 1998, p. 99). However, an empirical test shows that even the ratios of 1.3 to 1 may produce recognizable factor solutions (Arrindell & van der Ende, 1985). Brouwer (1992-93) demonstrates the feasibility of using the same data for both Q and R analysis from a case of 80 variables with 54 observations. On balance then, R factor analysis at Q workshop is conducted for the sake of illustrating the relative positioning and partitioning of perspective in a schematic figure, not for determining a definitive and statistically rigorous picture of the configurations of data.

Q mapping

The two-factor solution provided by R analysis transforms the similarities in participants' individual Q scores into distances represented in two-dimensional space as in Figure 1. The horizontal axis and the vertical axis in the above figure represent the normalized factor scores of Factor 1 and Factor 2, respectively. In this example of a stakeholder analysis, on the horizontal axis the view spreads from 'substantive' in which people observe that the social appraisal of nuclear technology is useful in positive terms, to 'symbolic' in which they are doubtful about this, seeing the utility more in political terms. The view on the vertical axis spreads from 'democratic' (under which it is seen that the appraisal involves a wide range of stakeholders and the public) to 'technocratic' (under which it is seen that the appraisal involves only a limited range of experts) (Yoshizawa, 2007, p. 239). The factor scores are computed by the regression method, which works by multiplying the factor loadings by the inverse of the original correlation matrix. Conceptually, the factor score represents the degree to which each individual score obtained through Q sorting rates high on statements that have high loadings on a factor. In Figure 1, each data point corresponds to the participant identification number.

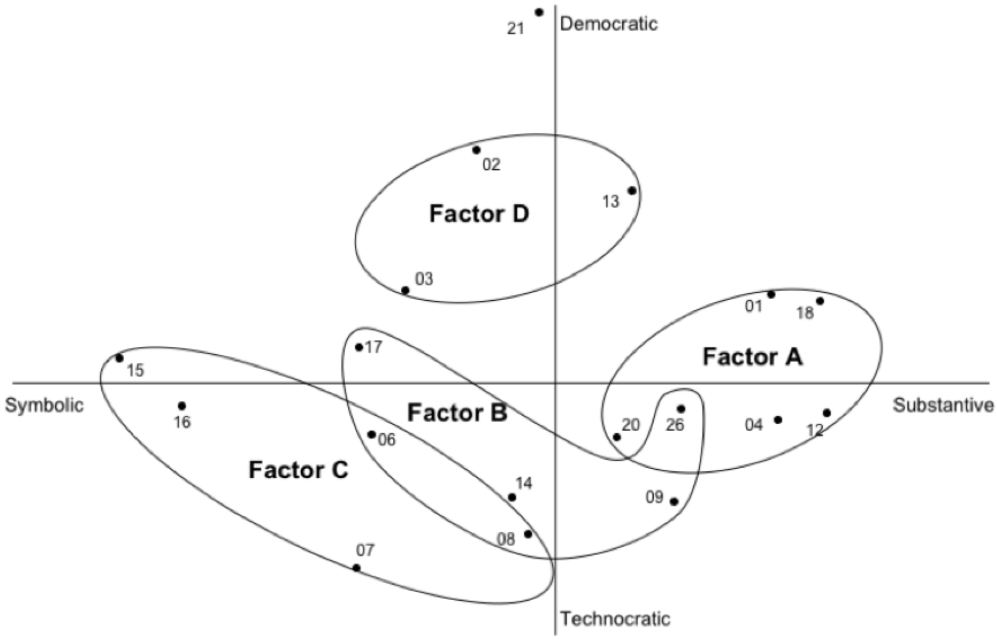

Figure 1. Example of a Q map

Perspectives from the Q factor analysis in Figure 1 are shown like a Venn diagram. Each closed curve represents an aggregate perspective. A conjunction between two closed curves means that participants therein share both perspectives. In the two-dimensional schematic figure, the Q result is overlaid on the R result. Each data point corresponds to an individual participant in the Q study. The position of the individual reflects the result of R factor analysis, whereas the group of individuals reflects the results of Q methodology. This makes Q mapping more analytically grounded than other methods that use pictorial representations of factors (Niemeyer, Petts & Hobson, 2005) or conceptual space diagrams on which various inter-factor relationships and differences in perspective are graphically but hypothetically represented (Stenner, Dancey & Watts, 2000; Watts & Stenner, 2005, 2012). Q map looks similar to the graphical representation of cluster analysis. Compared to cluster analysis, Q factor analysis is a more promising method to classify participants (Morf, Miller & Syrotuik, 1976), but the number of categories formed is large and the category profiles are less mutually exclusive with considerable overlaps (Chatterji & Mukerjee, 1986). As Figure 1 shows, Q mapping can take this disadvantage as an opportunity in disguise by depicting inter-factor relationships and illustrating overlaps of the factors. Even within a group, a participant can understand his or her own positioning in the group.

Factor interpretation

The partitioning and relative positioning of perspectives in a schematic way illustrated by Q mapping helps us to understand the result of Q methodology in a visually intuitive manner. It further facilitates participants' understanding of the self and others through the deliberation of Q mapping results. Although it is possible and reasonable in some cases for the investigator to collect Q sorts from the participants respectively through a face-to-face interview and draw a Q map afterwards (e.g. Yoshizawa, 2007), Q mapping is probably a more promising tool for settings where all the participants gather and conduct Q sorts individually in a workshop style. As described in more detail later, the latter case gives an opportunity for the participants to look at the configuration of different perspectives on the resulting Q map and reflexively learn their own position in the whole configuration. Through this process they will likely gain a better understanding of how to communicate and interact with other participants, as well as with non-participating stakeholders and citizens.

A Case: STS Education

The case study was conducted in a workshop on science and technology policy for postgraduate students in the Graduate University for Advanced Studies (known as 'Sokendai') in Japan. Sokendai is a university affiliated with research institutes and museums (IURIs: Inter-University Research Institutes) administered by the Ministry of Education, Culture, Sports, Science and Technology (MEXT). As Sokendai has no special facility in the IURIs, students are mentored at Sokendai both by the faculty of Sokendai and of the IURIs. Their disciplines significantly vary and their affiliated IURIs are located all over the world. Thus, for them and Sokendai itself, it is crucially important to gather postgraduate students at one place and facilitate interdisciplinary knowledge exchange and mutual learning. The three-hour workshop was conducted on July 15, 2012 as a part of the annual two-day introductory event for postgraduate students who want to be researchers.

P set

The workshop participants as Q sorters consisted of 12 postgraduate students and 4 academic researchers mostly based in Sokendai. Their participation in the workshop was voluntary, which meant that investigators did not strategically select the participants. The P set may have been more biased than random sampling in the sense that volunteers are presumably keen to tackle with the issue at hand. However, this exercise itself did not aim to pursue academic rigor or explore social implications. The number of Q sorters might not be sufficient to conduct proper Q analysis and get a neat set of factors, but with hindsight the number was sufficient, as concerned participants were more familiar with thinking about the given issue and therefore had clearer and more consistent views on the topic than other postgraduate students who were not necessarily interested in the issue.

Q set

Statements were collected by deliberative sampling. Each participant was asked to think up 4 or 5 one-sentence statements replying to a question "who should do what for social contributions to research?" and write down these on sticky note. A facilitator asked the participants to devise short statements that specify who should do what. Then, they presented their statements in turn. When one's presented statement was the same as or similar to another's statement in hand, these were shared with everybody at the same time. Later presenters only showed unique statements that had not already been presented. Statements were input into a computer and simultaneously projected onto a screen. The facilitator checked all the statements with the participants and similar statements were consolidated. The final set of statements was once again shared with everybody. This interactive process lasted about 40 minutes and ended up with 37 synoptic statements.

Q sort

This case analysis followed the standard Q sorting procedure and adopted 37 sample statements on social contributions of research. Immediately after the Q set was finalized, each of the 37 statements was printed out on blank business cards numbered from 1 to 37. Although random numbering is preferable in order to disconnect any relations between statement and number, the numbering was more or less in the order of participants' presentation and/or facilitator's arrangement for the sake of convenience. Participants were asked to thoroughly shuffle and rank cards according to the sorting grid illustrated in Figure 2.

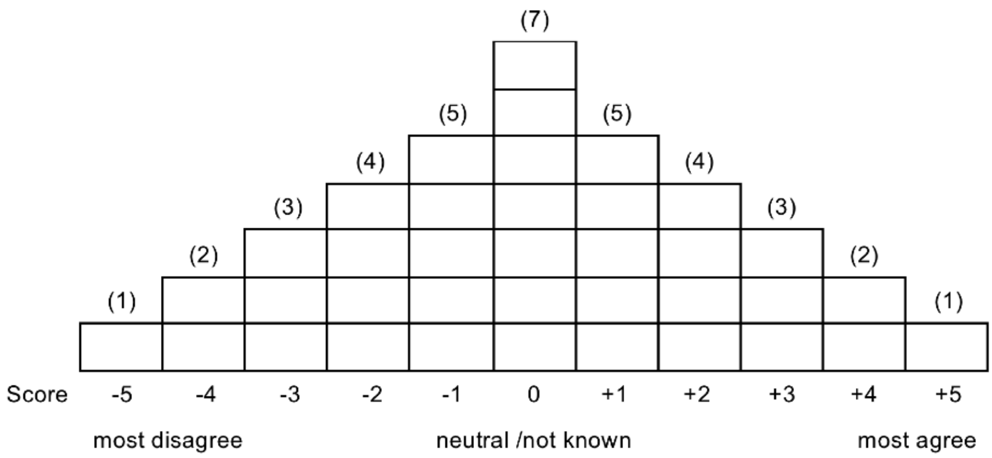

Figure 2. **Q sorting grid for 37 statements**

They were then asked to transcribe their sort onto the sorting grid depicted in a response sheet. The sheet also listed the following questions.

- Why did you choose the statements you most agree with?
- Why did you choose the statements you most disagree with?
- Are there any curious statements or any other issues in the sorting?

The answers were to be used by the investigator for the reflection and the feedback during and after the workshop exercise.

Q factor analysis

This case study employed the centroid method to extract factors and varimax rotation to have a meaningful pattern of factor loadings. A Q factor analysis for the 16 participants led to the factor solution shown in Table 1. Factor loadings in excess of ±0.42 are statistically significant at the 0.01 level. However, in order to facilitate participants' mutual learning by categorizing each of them into one group, this study used flagging factors automatically calculated and indicated in PQMethod. Flagged loadings are represented in bold text and shaded grey for ease of identification in Table 1. Participants are numbered according to the significant factor loadings for each factor.

Table 1. Participants' factor loadings

				Factor Loadings		
ID	Sex	Status	Discipline	Factor A	Factor B	Factor C
1	M	Professor	Science and technology studies	**0.68**	0.08	-0.31
2	F	Student	Physiological science	**0.62**	0.36	0.36
3	F	Student	Food and nutritional science	**0.62**	-0.08	0.22
4	F	Postdoc	Science communication	**0.60**	0.04	-0.00
5	M	Postdoc	Science and technology studies	**0.59**	0.04	0.19
6	M	Student	Fusion science	**0.51**	0.09	0.20
7	F	Student	Evolutionary studies	**0.42**	0.01	-0.04
8	M	Student	Applied biological chemistry	**0.42**	-0.22	0.20
9	M	Student	Evolutionary studies	0.46	**0.77**	-0.04
10	M	Professor	Quantum chromodynamics	0.15	**0.52**	-0.04
11	M	Student	Molecular genetics	0.02	**0.40**	0.10
12	M	Student	School education	-0.14	**0.39**	0.12
13	M	Student	Molecular genetics	-0.10	-0.23	**0.59**
14	M	Student	Space energy engineering	0.13	0.25	**0.44**
15	M	Student	Materials structure science	0.22	0.16	0.24
16	M	Student	Higher education	0.15	-0.32	0.14

R factor analysis

The resulting Q sorts were independently factor analyzed. Factor extraction, rotation and factor score computation were processed by the dedicated Excel macro program (Aoki, 2006). Statements with the highest 5 and lowest 5 loadings are regarded as the variable representative of the factor. In the end, all statements, except one (#28 for Factor 2, see Table 4), had factor loadings of more than ±0.40. These important functions contain some 'noise', but this may well characterize each factor in the following interpretation.

Table 2. Statements with the 5 highest factor loadings for Factor 1

#	Statement	Loading
15	Research institutes should hold open lectures	.642
33	Researchers should pass down the fun of science for future generations	.618
17	Universities should contribute to society with research findings	.596
22	Students should study their fields of interest in the first place	.511

1	Mass media should cover even minor discoveries and post-doc research	.498

The statements with higher loadings for Factor 1 referred to as "working with the outside world", include many that universities, research institutes and researchers themselves need to communicate the fun and interest of science and research findings with society. At the same time, mass media are expected to pick up small findings, which students should study carefully (Table 2).

Table 3. Statements with the 5 lowest factor loadings for Factor 1

#	Statement	Loading
19	The government should foster research administrators and networkers	-.788
30	Universities should foster research administrators and networkers	-.657
9	Off-campus networkers should promote research	-.639
34	Graduate schools should provide university-wide career education	-.577
24	University should teach undergraduate students about social action	-.542

Lower loadings for Factor 1, labeled as "strengthening inside the academia", are associated with statements that prioritize research administrators and networkers to researchers themselves and therefore need to support such human resources by government institutions and under- and post-graduate education (Table 3).

Table 4. Statements with the 5 highest factor loadings for Factor 2

#	Statement	Loading
6	Companies should appreciate research career in recruiting	.701
31	Public sectors should assure basic management expense at the same level as before the transformation of incorporated administrative institutions	.700
10	University research administrators should generate ideas for research application which researchers may not be able to think of on their own	.593
1	Mass media should cover even minor discoveries and post-doc research	.516
28	The government should enhance international competitiveness by supporting gifted young researchers	.391

The statements with higher factor loadings for Factor 2 concern the support of researchers by the government, public sectors, companies, mass media and university research administrators, and can be termed as "social supports" (Table 4).

Table 5. Statements with the 5 lowest factor loadings for Factor 2

#	Statement	Loading
35	Individual scientists should disseminate current issues and limitations of their discipline	-.765
8	Researchers should think about how their research area can address social issues	-.717
3	Mass media should pay attention to social problems in a skillful manner	-.636
16	Universities should offer classes to the general public	-.584
37	Researchers should communicate with researchers working in different	-.556

disciplines

The statements with lower factor loadings for Factor 2 are named as “self-help researchers”. They ask researchers to think about research issues and possible social contributions and communicate with other researchers in a transdisciplinary way. In order for researchers to look outward, it is necessary that mass media to cover social problems and universities become more open to the society (Table 5).

Q mapping

The above two-factor solution transforms the similarities in participants’ individual Q scores into distances represented in two-dimensional space. In the workshop, data points were first displayed without an index (Figure 3). The workshop facilitator asked participants to guess which data point is his or hers own from a data plot with 4 labels at both extremes of the horizontal axis (“working with the outside world” and “strengthening inside the academia” for Factor 1) and the vertical axis (“social supports” and “self-help researchers” for Factor 2). Each participant put his or her name at a guessed data point.

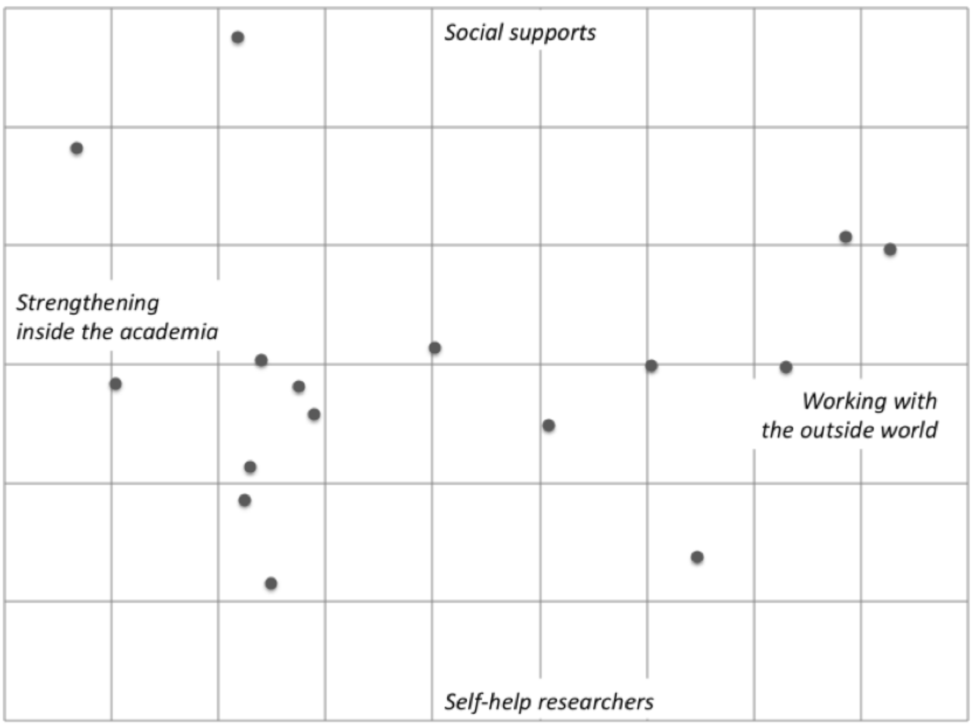

Figure 3. Q map (in process)

Then, the facilitator showed the figure with the name assigned to each data point (in Figure 4, the names are replaced with serial numbers for the sake of anonymity). The result illustrates that some guessed correctly while others guessed incorrectly. This purpose is not to evaluate the correctness of their conjectures but rather to attract attention to and increase awareness of the relative positioning of their mental models. All of the closed curves are manually drawn in the shape of ovals for clarity of presentation and this does not reflect the outcome of statistical calculation.

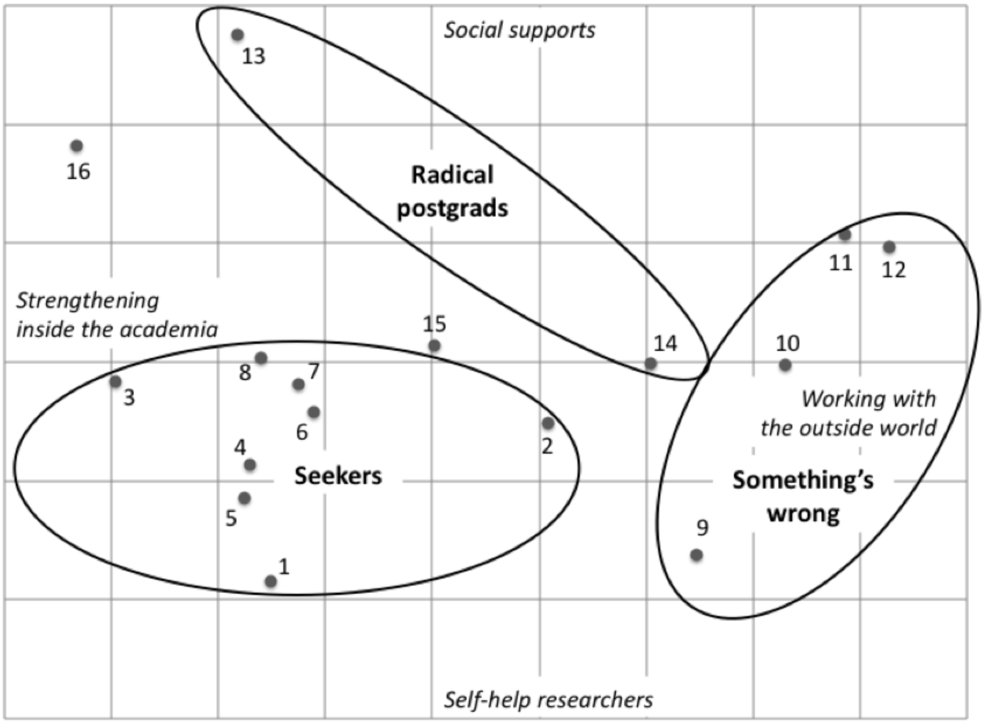

Figure 4. **Q map (completed)**

Factor interpretation

In the workshop, participants were divided into three groups according to the three-factor solution of Q methodology. Each group discussed what is characteristic of the group by looking at the results of Q methodology and the positioning and partitioning of the group on the Q map as well as the response sheets. The facilitator then asked each group to determine the group name and to give short presentation on the discussion results in turn. This process developed a sense of intimacy between group members and their collective identity. Positioning of each perspective in this schematic field is explained in the following.

8 participants (including 3 researchers) have significant positive loadings for Factor A and form the largest group. Table 6 shows statements significant at the 0.05 level (asterisk indicates at the 0.01 level) for Factor A and their factor scores with each factor. Factor scores are the ranked items converted back into the original Q sort distribution in order to create a factor array for each significant factor. The group members primarily support statements like "researchers should think about how their research area can address social issues" [#8] and "researchers should locate their own research in the whole research field and imagine the application of the research" [#36]. Through the discussion they became aware of how to link their own technology and knowledge with societal problem solving and their position among various research areas. On the other hand, in favor of "strengthening inside the academia", they did not prioritize statements like that researchers are to be supported and research environment is to be arranged by society. Therefore they called themselves "seekers" in the sense that they did not expect much support from others.

Table 6. Factor A – "Seekers" group

#	Statement	Factor Scores		
		A	B	C
8	Researchers should think about how their research area can address social issues	5*	3	0
36	Researchers should locate their own research in the whole research field and imagine the application of the research	**4***	2	3
26	Researchers should share common interests with general public	**3***	-1	-2
19	The government should foster research administrators and networkers	3	-1	0
24	University should teach undergraduate students about social action	**2***	-4	-1
3	Mass media should pay attention to social problems in a skillful manner	2	-1	-1
22	Students should study their fields of interest in the first place	2	3	-3
29	The government should provide student aid	**0***	4	3
25	Scientists should communicate not only the fun of their own expertise but also that of science in general	0	3	-2
10	University research administrators should generate ideas for research application which researchers may not be able to think of on their own	**0***	-2	4
5	Companies should exchange more information with universities and research institutes	**0***	-3	3
16	Universities should offer classes to the general public	**-2***	2	-4
17	Universities should provide the society with research finding	**-2***	2	2
15	Research institutes should hold open lectures	**-3***	1	1
1	Mass media should cover even minor discoveries and post-doc research	**-5***	0	-1

The second major group, in which 4 participants have significant positive loadings for Factor B, called themselves "something's wrong" (Table 7). This colloquial name comes from that they have similarities in negative aspects of companies and universities. They appear to have features in common with "working with the outside world", but they are slow to get work done, and even when working, they rely on social institutions for support. Indeed they analyzed their ineffective workability from the fact that this team could not wrap up discussion due to under-utilization of workshop tools such as sticky notes and large paper.

Table 7. Factor B – "Something's wrong" group

#	Statement	Factor Scores		
		A	B	C
8	Researchers should think about how their research area can address social issues	5	**3***	0
25	Scientists should communicate not only the fun of their own expertise but also that of science in general	0	**3***	-2
22	Students should study their fields of interest in the first place	2	3	-3
21	Students should organize Science Café and community engagement as best they can	-1	**2***	-2
16	Universities should offer classes for the society	-2*	**2***	-4
33	Researchers should pass down the fun of science for generations	-1	1	-1
11	The government should provide support for the employment for a new field	-2	**1***	-3
13	Academic societies should disseminate more information to the public	1	**-2***	1
10	University research administrators should generate ideas of research application which researchers may not be able to think of on their own	0	**-2***	4
9	Off-campus networkers should promote research	1	**-3***	0
34	Graduate schools should provide university-wide career education	2	**-3***	0
5	Companies should exchange more information with universities and research institutes	0	**-3***	3
24	University should teach undergraduate students about social action	2	**-4***	-1

The last group comprises of 2 participants with significant positive loadings for Factor C (Table 8) and two other participants (Participant No. 15 and 16 in Table 2). As they explain, the group name "radical postgrads" means it is typical of postgraduates that everyone has radically different pointed remarks. Despite the relatively high factor score, they all disagree with "companies should support research for non profit" [#4] in the sense that the support from companies is just a part of their corporate social responsibility (CSR) activities and not so realistic for us to expect. There are pros and cons for supporting young researchers but they would normally expect "social supports" of researchers to be socially contributive.

Table 8. Factor C – "Radical postgrads" group

#	Statement	Factor Scores		
		A	B	C
6	Companies should appreciate research career in recruiting	-3	-2	**5***
10	University research administrators should generate ideas of research application which researchers may not be able to think of on their own	0	-2	**4***
28	The government should enhance international competitiveness by supporting gifted young researchers	1	1	**4***
5	Companies should exchange more information with universities and research institutes	0	-3	**3***
4	Companies should support research for non profit	-4	-5	**2***
31	Public sectors should assure basic management expense at the same level as before the transformation of incorporated administrative institutions	-4	-4	**1***
37	Researchers should communicate with researchers working in different disciplines	3	4	**1***
8	Researchers should think about how their research area can address social issues	5	3	**0***
35	Individual scientists should disseminate current issues and limitations of their discipline	4	5	**0***
24	University should teach undergraduate students on social action	2	-4	**-1***
25	Scientists should communicate not only the fun of their own expertise but also that of science in general	0	3	-2
22	Students should study their fields of interest in the first place	2	3	**-3***
16	Universities should offer classes for the society	-2	2	**-4***
27	Research supervisors should contrive ways to instruct researchers	-1	0	**-5***

Methodological Reflection

Q methodology has been recognized as a hybrid of qualitative and quantitative methods, often being called 'para-quantitative approach' (Capdevila & Stainton Rogers, 2000) or 'qualiquantology' (Stenner & Stainton Rogers, 2004) because it does not follow the hypo-deductive format that quantitative methods normally use (Watts & Stenner, 2005). Despite this hybridity, a growing number of studies have attempted to further combine Q methodology with other quantitative or qualitative methods. Past attempts often put more attention on interviews, questionnaires and surveys to increase the validity and effectiveness of a Q methodological study (Rutherford, Gibeau, Clark, & Chamberlain, 2009;

Danielson, 2009; Gallagher & Porock, 2010; Franz, Worrell & Vögele, 2013; Kim & Lee, 2015).

As the above case study illustrates, person samples grouped (according to the Q factor analysis) are positioned with reasonable conjunctions, concentrations and partitions on a two-dimensional distribution space (according to the R factor analysis). In other words, the two distinct factor-analytic methods achieved comparable results and validated one another by methodological triangulation. A recent study demonstrates strong similarities between Q and R results under identical sampling conditions (Thompson et al., 2012), but the hybridization in Q mapping supports the basic idea that the "[s]elf is not a categorical construct in Q, rather it is thoroughly contextual, discursive, and social. It is formative, emergent, and contingent, an empirical abstraction prone to elaboration and understanding rather than reduction" (Goldman, 1999, p. 592). This suggests that emergence and interaction between participants in Q workshop can be legitimate in Q methodology. Q workshop can be a powerful candidate of 'opening-up' elicitation and deliberation techniques to employ pluralistic discourse in participatory appraisal, exploring systematic divergences of perspective (Stirling, 2008; Stirling et al., 2007). When Stephenson proposes that the theory of communication ignores facts and concerns itself only with meanings (Stephenson, 1978), Q workshop is keen to follow the basic tenet of the theory in that participants can facilitate mutual communication of their understandings of Q sort, Q map and Q factor arrays. This heuristic employs a process of abductive reasoning via intensive procedures to examine substantial relations of connections in causal groups (Danermark, Ekström, Jakobsen, & Karlsson, 2002; Watts and Stenner, 2012). Q workshop successfully connects individual learning with collective learning by constructing Q sorts as individual mental models, which are then shared by Q factor array and by illustrating the difference of shared mental models on the Q map. In fact, according to follow-up comments from the participants after the above case event, 5 out of 10 students positively referred to the Q workshop exercise as a surprising finding of their own perspective in relation to others.

Q methodology is closely related to narrative analysis in illustrating "the particular *combinations* or *configurations* of themes which are preferred by the participant group" (Watts and Stenner 2005, p.70, emphases in original). Like concept mapping, Q methodology uses predetermined structures and a rather strict set of rules for creating these visual representations and may provide individuals with a lower degree of freedom to express their own concepts (McNeil, 2015). Q sorting as an explicit simplified, one-dimensional mental model (de Haas & Algera, 2002) appears to further reduce the degree of freedom. Under the circumstances, participants may have to generate their own narratives about the given issue whilst establishing a consistent rank order criterion. Narratives in the deliberation and discussion of the results of Q mapping between participants are worth investigating for further analysis.

Conclusion

Q workshop is not just recognized as a tool for the hybridity of qualitative and quantitative methods as a derivative of Q methodology, but rather as a legitimately useful tool to explore the plurality of perspectives in a systematic and deliberative way by reflecting on the formative, emergent, and contingent aspects in Q. The present study takes an empirical case on STS education for postgraduate students, from which we observe that the use of R factor analysis in conjunction with Q methodology can play a heuristic and abductive role in providing independent illumination of the distinguishable perspectives, suggesting a schematic two-dimensional basis for resolving the key differences.

Over the last five years we have been confident of the practical utility of Q workshop by applying it to a number of cases, including technology assessment for future living, science communication for graduate education, technology foresight and strategy for a trading company management, and dialogue for innovation by forging university-industry links. We recently developed a dedicated Excel macro software for Q mapping that runs PQMethod in the background and reflects its results on the Excel sheets. Further studies would develop methods for evaluation of individual and collective learning at Q workshop by focusing on the change of mental models, or conceptual change (Duit & Treagust, 2003; Treagust & Duit, 2008; Chi, 2008). The evaluation can be performed through construction interactions among group members (Miyake, 1986, 2008; Shirouzu, 2010), or by measuring the difference of Q maps before and after group discussions during the course of Q workshop.

The two-dimensional map of perspectives generated in this study might be usefully applied in other cases and more general contexts – even without the employment of the Q-sort technique. A further elaboration of such quantification and graphical visualization techniques, by which individual actors can understand the partitioning and relative positioning of perspectives (including their own), should be able to provide us with more accountable, persuasive and reflexive measures.

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