Participation and competence as joint components in a cross-national analysis of scientific citizenship

1. Introduction: PUS at the crossroads

In the 2000s, Public Understanding of Science – as a research programme and as a social movement (Bauer 2003) – appears to be approaching a significant crossroads (Miller 2001).

On the one hand, social scientists and science communicators can travel the path that has been dominant within the field – not least in the UK – since the Royal Society in 1985 published the influential Bodmer report, urging the scientific community to intensify knowledge dissemination from science to lay citizens. In few words, the main aim within the dominant approach to science-citizen relations has been the advancement of *scientific competence* – both in terms of 'objective' knowledge of scientific results and methods and 'subjective' interest in and attention to science - among the general public. Lack of public competence in matters of science and technology is believed to have important social and economic consequences. First, inadequate knowledge of the science and technologies that pervasively shape modern social systems seriously challenges the constitutive idea of a democratic society, in which every citizen has equal opportunities. Public knowledge about matters of science and technology serve to empower citizens to navigate successfully in the knowledge society and science dissemination can be seen as a way to create an opportunity structure by providing the tools and skills for efficient human agency. Secondly, lack of public interest in and knowledge of science makes it more difficult to sustain and develop the systems of innovation and the strategic technologies on which economic performance is increasingly being based. As such, public competence in science is both a matter of cultivating an enlightened citizenry (Elam & Bertilsson 2003), and an important prerequisite for keeping economic pace (Healey 1999).

On the other hand, the research community and communication practitioners may decide to take another direction, towards studying patterns of citizen engagement with science and facilitating more active public involvement in science and technology decision making. Where the dominant approach has been focused on the deficit of public competence, new diagnoses are emerging, that tend to be more concerned with the deficit of mutual trust between scientists and citizens and the lack of active public participation in decision making processes regarding science and technology (Durant 1999). The emerging PES – or Public Engagement with Science – approach involves a change of format of science communication. Whereas the competence approach is primarily concerned with one-way translation and dissemination from science to passive citizens, the participatory approach is experimenting with new formats that involve direct interaction, dialogue, and participation in a two-way communication, where citizens can in fact 'speak back' to science (Gibbons 1999), make their concerns heard to scientists as well as science policy-makers, and contribute to setting the agenda for research. These formats include citizen juries, scenario workshops, consensus conferences, citizen panels and other activities (Banthien, Jaspers & Renner 2003) that often are normatively anchored in theories of deliberative democracy in which the participatory dimension is central (Joss & Durant 1995). The emerging program is striving to create a strong culture of citizen involvement in issues of science and technology. As such, the main concern of communication activities is now increasingly about public *participation* rather than public competence.

The competence approach and the participation approach have been portrayed as incompatible, competing models of the science-society relation. Illustratively, Michael & Brown (2005: 41) describe the PUS field as a scale, where the poles are represented by the competence and participation approaches respectively:

> 'One pole is occupied by the Positivist (or Traditional) approach with its emphasis on survey analyses of the contents of the public understanding of science and of attitudes towards science. At the other end sits the Interpretationist (or Critical or Ethnographic) perspective which deploys qualitative techniques (interviews, ethnography) to embed public knowledge within its local cultural context and in relation to broader institutional agendas […] If the former aims to measure the public's scientific literacy, the latter explores the public's identity and trust in scientific institutions. Where the former aspires to educate the public and thus enfranchise it, the latter traces the ways in which the public's local knowledges are marginalized by the scientific institutions. For the former the public is comprised of cognizing individuals who must be changed (corrected, educated) by scientific institutions, for the latter, lay people are social beings that are part of local communities whose views are sufficiently important to require change in scientific institutions'.

Although Michael & Brown recognise that the division is somewhat crude, it is clear from the excerpt that the two approaches are considered fundamentally in conflict with each other (they are really poles apart). It is also clear that the incompatibility is due to multilayered differences. Hagendijk has distilled these layers as a ‘triple’ divide in PUS studies. First, there is a straightforward methodological divide between quantitative (often survey-based) approaches on one hand and qualitative approaches (often based on interviews, observational fieldwork, or historical analyses) on the other hand; which is based on a second (epistemological) divide between a conception of science as either detached from or contingent upon social and political conditions. In turn, the methodological and epistemological divides link up with a political or philosophical divide that concerns the role of citizens as members of the knowledge society. The ‘positivist’ image of science as a disinterested, detached, system of laws, truths, and facts, basically:

> ‘..favours an elitist, or at least a meritocratic view of decision making. Thus, those who lack the proper competence [...] should either be educated or marginalized in decision making. Equally, it follows that opposition from non-experts stems from ignorance’ (Hagendijk 2004: 44).

Conversely, a conception of science and technologies as social, contested, practices, and an emphasis on the co-production of scientific knowledge and socio-political order (Jasanoff 2004) would imply a democratic view on decision making, in which non-experts – or simply lay citizens – legitimately raise demands on science and participate in the societal assessment of and debate about science and technologies.

According to this line of reasoning, then, PUS at the crossroads involves a decision between two coherent, normative models, each offering a separate formula on how to study, discuss, and organize the science-citizen relations: One is basically concerned with surveys, pure science, and citizen competence. The other is about qualitative studies, co-production of science and society, and citizen participation.

2. A possible third path: Scientific Citizenship

What we would like to explore in this article, is whether the battlefield-narrative of competence vs. participation is really necessary. We propose a third path that does not delimit itself to either one or the other. We think that the question of how to discuss, analyze, and assess the role of citizens in knowledge societies should not be an either/or – participation or competence – but a matter of examining the balance and interconnectedness of both.

One way to get beyond the PUS / PES dichotomy, or to 'liberate the agenda' as Bauer, Allum & Miller (2007) have put it, might be to think about competence and participation as interrelated dimensions of 'scientific citizenship'. Horst (2007: 151) provides the following definition of scientific citizenship:

> The notion of scientific citizenship (Irwin 2001) points to an increasing awareness of the intermingling between science and society. It implies not only that scientific knowledge is important for citizenship in contemporary society but also that citizens can lay a legitimate claim about accountability on scientific research. As such, the notion can be perceived as a normative ideal concerning the appropriate form of democratic governance in a society that has become increasingly dependent on scientific knowledge.

The argument she makes is exactly that scientific citizenship is two-dimensional: First, scientific competence is a prerequisite for effective human agency in modern societies. In an increasingly complex world, where science and technologies extensively shape the everyday lives of the public and affect social practices, citizens are in need of particular competences, knowledge and skills, to navigate effectively and define their own role within the system. We might also say in line with traditional conceptions of citizenship, that citizens in modern societies have a *right* to be informed, by means of appropriate dissemination schemes, about the developments, potentials and risks alike, in science and technology, in order not to be marginalised from social systems.

Secondly, as Horst argues, providing knowledge to citizens is not an exhaustive parameter of scientific accountability. Scientific competence may facilitate human action and cultivate an enlightened citizenry; however, there is also a need for mechanisms to ensure that citizen concerns are in fact fed into decision-making processes. If modern societies are to be considered legitimate, citizens should thus also actively make use of their competence to lay claim on scientific practices and take part in public debate about scientific and technological developments. The inherently normative notion of (republican) participatory citizenship stresses the importance of full citizenship in terms of both certain rights and privileges, which serve to protect and empower the individual on the one hand, but also – and equally important – an ideal of civicness as a sense of societal obligation or *duty*, in which participation is a virtue (Sandel 1996; Barber 1984). Participatory citizenship is not simply about enjoying the right to enter the sphere of decision-making, but rather about actually entering it. In terms of a ‘full’ scientific citizenship, then, we might say that scientific competence makes it possible, and actual participation makes it happen.

What we wish to explore in the succeeding parts of this article, then, is the empirical relationship between citizen competence and citizen participation, based on survey data. We propose that a first step towards developing models or typologies of scientific citizenship is to construct solid measures of citizen competence and citizen participation and examine their interconnectedness. There is no single dominant approach in the current literature to measuring elements of scientific citizenship. Contributions include, for example, measures of levels of *interest* in science (Evans and Durant, 1995); Miller’s classification of the *attentive*, *interested* and *residual* publics for science (Miller and Pardo, 2000) and for biotechnology (Miller and Kimmel, 2001); *awareness* of biotechnology (Miller and Kimmel, 2001); *informedness* (Pardo, Midden and Miller, 2002); and more general *engagement* (Gaskell et al., 2006). The literature on measuring scientific knowledge is too extensive to document here. We mention simply that the main approach to measuring scientific *knowledge* in surveys is by means of a series of statements about science, which respondents are asked to judge as true or false. This approach has been developed significantly by Jon Miller in the US (e.g. Miller, 1998) and John Durant and colleagues in the UK (e.g. Durant et al., 1989), and has received a good deal of attention and critique, from both substantive and methodological perspectives – particularly in terms of its cross-cultural validity (e.g. Peters, 2000; Pardo & Calvo, 2004). Indeed, a fundamental concern in developing indicators of competence and participation is the degree to which they can be applied across cultural settings. In this paper we focus on the European public, and assess the statistical comparability of our measures between countries within Europe – a small first step towards addressing a complex methodological issue.

3. Data

In terms of developing appropriate indicators of citizen competence and – particularly - participation, we make use of the most recent European survey on ‘Europeans, Science and Technology’ (EB 63.1) fielded in 2005 in 32 countries (listed in Tables 4 and 6), with a total sample size of 31,390. It distinguishes itself from previous European PUS surveys by including a number of items on actual – as opposed to intended – behaviour, and the items on participation also differ from items applied in earlier surveys by broadly gauging public participation in science-in-general instead of confining the items to participation concerning a particular scientific field, such as biotechnology. The analyses in this paper focus on two sets of variables, capturing participation and competence. Table 1 below gives frequencies for these items for the complete data set, with each country's contribution to the total weighted according to its population size.

Table 1 about here.

4. Analyses

The objective for our analyses is to use the items described above to explore the feasibility of cross-national indicators of participation and competence. We employ latent class models (Lazarsfeld & Henry 1968) for this purpose, rather than using an a priori scheme to classify or rank respondents on these attributes. Using latent class models, we posit that the associations between the survey items described above are a function of some underlying, general variable characterising an element of scientific citizenship – participation or competence. These constructs, like many others in PUS, are not tangible – they cannot be observed directly. They are rather hypothesised, *latent* variables, presumed to lie beneath the observed survey responses, and we infer their existence from the associations between the survey items. For our study, a latent variable approach to creating measures of scientific citizenship has two advantages over an a priori classification of responses. Empirically, it allows the data to 'speak' for themselves, which is particularly useful for exploratory work on indicator construction. Conceptually, it specifies a probabilistic rather than deterministic relationship between survey responses and attributes, allowing for the possibility of measurement error in the observed items – an approach widely endorsed by attitude measurement theorists (e.g. McKennell, 1979). We implement the models in the programme Latent GOLD, version 4.0 (see Vermunt & Magidson (2005) for technical details)[1], treating the concepts of participation

[1] For transparency, we briefly note here the key technical specifications used with this programme. First, we employ the default 'Bayes constants' to avoid boundary solutions, that is estimated probabilities of 0 or 1. Since these are vague priors, they make very little practical difference to our results: the estimates from models using

and competence as discrete variables, with a number of categories, or classes. In keeping with the exploratory nature of the analysis, no assumptions are made about the rank ordering of the classes in relation to attributes they represent: they are specified as unordered (nominal), statistically speaking.

The basic latent class model can be specified as follows:
x is a categorical latent variable, with q unordered categories $j=1,\ldots,q$; and
y_i ($i=1,...,p$) are p observed or manifest variables, where y_i has c_i categories $s=1,..., c_i$.

We model the probabilities of belonging to class j:
$\eta_j = \mathrm{P}(x=j),\ j=1,\ldots,q$
and the conditional response probabilities:
$\pi_{is}(j) = P(y_i=s|x=j)$,
that is, the probability of responding in category s to item i, given membership of latent class j.

We inspect the estimated conditional probabilities $\pi_{is}(j)$ to reach an interpretation of a latent class model. For example, we might notice that for people in a certain class, there are high probabilities of having read articles about science, having talked with friends about science, and of having attended public meetings about science. We could say that such a pattern of likely responses denotes a high level of participation, and label the class accordingly. We would then inspect the remaining classes in the model in the same way, looking for patterns in the most likely sets of responses in each of the classes. Having reached an interpretation for the latent classes, we might also be interested in the proportions of people expected to belong to each of them; this information is given in the class probabilities, η_j.

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them are very similar to Maximum Likelihood estimates. Secondly, to avoid the potential problem of iterations converging to a local rather than a global maximum of the likelihood function, each estimation run begins with a hundred sets of random starting values, from which Latent GOLD automatically chooses the best, and proceeds to calculate model parameter estimates from them. Thirdly, the joint cross-national latent class models presented are estimated applying a two-step weighting procedure available in Latent GOLD and recommended by the authors of the programme (see Vermunt & Magidson, 2005, for details). The estimated class probabilities are given for each country applying basic case-level weights, and for the 32 countries together weighted according to their relative population sizes. Lastly, we treat the small numbers of 'don't know' responses as missing, and use full information maximum likelihood (FIML) estimation to avoid listwise deletion of respondents who give one or more 'don't know' response.

In the joint cross-country models, we introduce country as a covariate, via a set of 31 dummy variables for the 32 countries. In each joint model, we allow the proportions of people estimated to belong to the different classes to vary between countries. But crucially, we fix the measurement part of the model (the conditional response probabilities) to be the same for each country – that is, we fix the 'ideal types' of response patterns to be the same, from country to country. If such a model fits satisfactorily, then we can say that the classes are composed in broadly the same way across Europe; that is, the patterns of associations between items are sufficiently similar between countries to enable us to speak of common classes of participation and competence.

Model fit can be assessed in a variety of ways, and we present a number of fit statistics for a selection of models (see Table 2). In identifying well fitting models we focus on two-way marginal residuals calculated from them[2]. This is based on an approach suggested in Bartholomew *et al*. (2002) drawing on Bartholomew and Knott (1999) and Jöreskog and Moustaki (2001). For responses to each pair of items, we create a two-way marginal table, by collapsing over responses to the other variables. We then compare *O*, the observed frequency in a single cell of such a table, with *E*, the expected frequency for that same cell. The residual for each cell is calculated as $(O\text{-}E)^2/E$, that is, in standardised version, where values greater than 4 are taken to indicate poor fit (Bartholomew *et al*. 2002). The greater the number of large residuals, the worse the model is. In the models presented below, the fit statistic we use is the percentage of standardised marginal residuals greater than 4[3]. In selecting joint cross-national models, we take into account the percentage of high standardised marginal residuals for the models as a whole, as well as conditional on country.

The following two sections consider participation and competence in turn, before exploring the relationship between them. For each construct, we first apply latent class models separately within each country sample to informally compare the common patterns of responses found from country to country. We then formally assess the comparability of patterns found, across

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[2] In addition to the statistic describing the proportion of large two-way marginal residuals, we include the following more conventional statistics: the likelihood ratio chi-squared statistic, L^2, number of degrees of freedom for the model and corresponding bootstrapped p-value (cf. Vermunt & Magidson 2005); AIC and BIC (e.g. Kuha 2004).

[3] These statistics are calculated using functions written by Dr. Jouni Kuha in S-PLUS software. Margins involving one or more missing ('don't know') response are not included in the calculation of these statistics.

the full data set, using country as a covariate in joint latent class models. Elements of both exploratory and confirmatory approaches are therefore entailed in these analyses. In terms of the former, we wish to explore the associations between responses to the items – that is, what types of typical response sets can we identify in the data? In terms of the latter, we wish to assess statistically the extent to which these patterns of associations can be said to hold across countries.

5. Results

Participation:

The results of the latent class analysis indicate that it is relevant to distinguish between *horizontal* participation on the one hand and *vertical* participation on the other. Horizontal participation in science and technology is concerned with the extent to which citizens engage in activities that enhance 'scientific culture' and inter-subjective learning. Reading about science and technology and talking with friends are 'non-political' modes of engagement that have an integrative quality and primarily represent a citizen – citizen perspective on issues of science and technology. Vertical participation, on the other hand, is concerned with the extent to which citizens take part in activities that are meant to affect decision making regarding science and technology, such as attending public meetings or debates and signing petitions or joining street demonstrations. Vertical participation aims at influencing policy-agendas and represents to a wider extent a citizen – system perspective on issues of science and technology.

It seems to be generally the case that responses mirror each other for the first two items capturing horizontal participation, as do responses to the second two, capturing vertical participation. That is, respondents who say they have read articles about science are also likely to say that they talk about science with friends. Likewise, those who say they sign petitions or join street demonstrations are also likely to say they attend public meetings and debates about science and technology. This pattern holds quite consistently between countries. Three-class models applied separately within each country identify, generally, a class each of highly participative and non-participative people (who answer positively to all items, or negatively to all items, respectively), and a class in which positive responses are given to the horizontal participation items, but negative to those on vertical forms of participation. The most notable deviation from this pattern is that in nine countries, those in the most highly participating group, on balance, will not engage in signing petitions or joining street demonstrations. We might say, then, that engaging in petitions and demonstrations is the highest hurdle in this set of items on participation.

Table 2 about here.

The variation between countries on this last item is too great to be reconciled in a cross-national model. A joint, cross-national three-class model, fits poorly[4]. Increasing the number of classes to four does not solve this problem: the fit improves a little, but the fourth class does not have a clear interpretation. However, if *petition* is dropped from the set, a three-class model fits well, across most countries[5]. A three-class model, using the remaining three items, is therefore our preferred cross-national measure of participation.

This model is described in Table 3, which shows the probabilities of the various responses for each item, conditional on class membership. Each class is represented by a column, and each item response by a row. Notably high probabilities are highlighted in grey. For example, conditional on membership in the first class in the table (looking at the first column of figures), a respondent has a 0.98 probability of saying he or she has read articles about science, a 0.99 probability of having talked about it, and a 0.67 chance of having attended a meeting or public hearing on the topic. Given such a pattern of likely responses for people in this class we could characterise it as one of both horizontal and vertical participation. This suggested label is included at the top of the column of figures, alongside suggested labels for the other two classes. The last row of the table gives the estimated probabilities of belonging in each class, weighted according to the relative population sizes of the 32 countries in the data set. For example, this model estimates that 42 per cent of this European public is highly participative (note that this is much higher than the 26 per cent of people who would be classed as highly

[4] In the model overall, 18.9 per cent standardised marginal residuals are greater than 4. Conditional on country, the model fits best in Ireland, for which 4.2 per cent marginal residuals are large, and worst in Greece, where 75.0 per cent are large. On average, conditional on country, 34.4 per cent standardised marginal residuals are greater than 4.

[5] Overall, 4.4 per cent standardised marginal residuals are greater than 4. Conditional on country, the range is from 0.0 per cent (in Belgium, Spain, France, Luxembourg, the Netherlands, Lithuania, Malta, Poland and Slovenia) to 50.0 (in Greece), with a mean of 13.5.

participative according to the model which includes petition as a criterion of high participation). Percentages of people estimated to belong to each class within each country are given in Table 4, with countries ordered according to the proportions of people estimated to belong to one of the two participating classes. In this initial study into developing indicators we would not attach too much importance to the rank ordering of the countries. But it is interesting to note some general intuitive patterns emerging – for example, many of the highly participative countries are from Scandinavia or elsewhere in northern Europe, whilst many of the countries with relatively lower proportions of participative people are from southern Europe. There is also an interesting variation in types of participation in different countries: for example, whilst roughly equal proportions of Swedes are found in the 'horizontal only' and 'horizontal and vertical' participation classes, in the Netherlands participation is much more likely to be 'horizontal only', and in Greece, those who participate are overwhelmingly likely to do so in both horizontal and vertical forms.

Tables 3 and 4 about here.

Competence:

We have tried to include items from the EB 63.1 that could potentially constitute a compound measure of competence that involves not only 'objective' textbook knowledge of science, but also 'subjective' competence, indicated by respondents' interest in science and what we could call internal 'techno-scientific efficacy', that is, the extent to which people subjectively *feel* well-informed on issues of science and technology.

As a preliminary analysis for these items, it is interesting to consider briefly the associations between the four questions on interest and informedness, that is, elements of subjective competence, which form their own set. In country-by-country analyses, whether four- or five-class models are applied, the following five types of competence emerge consistently:

- Very interested, very well informed
- Very interested, moderately well informed
- Moderate to all
- Moderately interested, poorly informed
- Not at all interested, poorly informed

Two interesting points can be taken from these models. First, they suggest that efficacy follows interest, rather than the other way around – we might perhaps say that interest is a prerequisite for feeling well-informed. Secondly, these patterns of responses apply both to new inventions and technologies, and to new scientific discoveries: people tend to give the same response to the pair of items asking about levels of interest, and the pair referring to informedness. These items work together so closely, in fact, that we might consider asking about one or the other, rather than both, in future surveys. For our purposes in finding a joint cross-national model for competence, we consider from this point just those items relating to 'scientific discoveries'.

The joint cross-national model, using these two items, and a third to denote levels of factual knowledge, is described in Table 5. To achieve a well fitting model[6] six classes are needed. Statistically speaking these are unordered classes (the latent variable is nominal), but for the purposes of substantive interpretation we can roughly order them, in common sense terms, from high to low competence. We can label them in terms of self-reported, subjective, competence (high, mid and low) and in terms of high or low text-book, objective, knowledge (+ or -). A six-class solution might be regarded as a little more complex than desirable, but considering that the three items yield 18 possible response patterns, a six-class solution nevertheless represents a considerable reduction in the complexity of the data.

In the six classes, the patterns of responses for interest and informedness appear again in a very similar way to our preliminary analyses. They also clearly show that there is no straightforwardly positive relationship between 'subjective' competence, as captured by interest and informedness, and 'objective' competence, as captured by the knowledge variable. It is, as for example in the case of the High- class, possible to feel rather competent even though the level of factual knowledge is probably low and *vice versa*. Nonetheless, the magnitudes of the response probabilities for these items give the suggestion of a weak positive relationship between objective and subjective competence: in the High+ group the probability of answering nine or more knowledge items correctly is 0.91, whereas in the Low++ group it is only 0.69; likewise the probability of having low objective knowledge is 0.73 in the High-

[6] Overall, 6.5 per cent standardised marginal residuals are greater than 4. Conditional on country, the range is from 0.0 per cent (in Belgium, Denmark, Croatia, Switzerland and Norway) to 52.4 (in Greece), with a mean of 13.4.

class, but 0.92 in the Low- class. It is therefore reasonable and useful to keep the three items together in a single measure of competence.

The estimated proportions of respondents in each of the classes, conditional on country, are given in Table 6, with countries ordered according to the proportion in the High + class, which defines high objective and subjective competence. Again some broadly intuitively plausible patterns can be identified in it – for example, Scandinavian and other northern European countries tend to be found towards the top of the list. However, alongside such patterns, some interesting details emerge. For example, in Greece, Malta, Cyprus and Turkey, large proportions of the public are classed as highly competent in subjective terms, even if they do not tend to have high levels of text-book knowledge about science. It is clear from the table that the distribution of competence, as defined by the model, is very varied amongst countries, particularly in terms of the relative distributions of and relationships between objective and subjective competence.

Tables 5 and 6 about here.

<u>Interrelatedness of competence and participation:</u>

We continue by examining the relationship between citizen competence and citizen participation in terms of the two measures above, using correspondence analysis to simplify the task of interpreting the large (three-by-six) resulting contingency table. The bi-plot in Figure 1 shows the relative strengths of associations between the classes: those classes which appear close together in the plot are relatively more strongly associated with each other than with classes which are further away. The plot suggests a positive association between participation and competence: those in the horizontal and vertical participation class are relatively more likely also to belong to the high competence classes than to the low competence classes, and those in the non-participative class are relatively more likely to belong to a low competence class than a high competence class. In broad terms, the horizontal axis explains much more (91%) of the inertia, or variation, in the contingency table, than the vertical axis does (9%). The horizontal axis ranks the classes from high to low participation (left to right), while the main function of the vertical axis is to draw a distinction between the 'low ++' class and the rest (in technical terms, this class provides the greatest contribution to the inertia of the dimension). Taken together the two axes appear to rank the classes along the diagonal from high participation and competence (top left) to low (bottom right), with classes representing high objective competence on the left of that diagonal, and low objective competence on the right.

Figure 1 about here.

6. Discussion

Our attempt to construct solid indicators of participation and competence shows that there are, cross-nationally, important distinctions that may qualify our understanding of the patterns of public competence and participation in science. First, based on the four items available on participation, it is relevant to make a distinction between vertical, policy-oriented participation and horizontal, 'culture-oriented' participation. This distinction makes sense in a citizenship perspective, where it is commonly used to distinguish between participation as an instrumental act of preference articulation in the wider formulation, passage and implementation of public policies (Parry, Moyser & Day 1992: 16) on the one hand and as an integrative act of creating collective values or 'social capital' (Putnam 1995) on the other. We anticipate that increasing the number of items on participation in future PUS surveys would allow us to further consolidate this result or / and identify other logical classificatory aspects of participation. Secondly, we have used a composite measure of competence that contains both 'subjective' and 'objective' elements, where a six-class model of competence has proven to travel well across 32 countries. It is noticeable that subjective and objective elements are not straightforwardly positively related. In understanding citizen competence, this distinction thus deserves attention, which also corresponds well with observations made in citizenship studies. Almond & Verba (1963) made this distinction between objective and subjective competence – and made a strong point out of showing how self-confident people are likely to be more participative - when they studied civic culture in five different nations in the early ‘60s. Others have divided citizen empowerment into an objective dimension, including formal and informal rights and opportunities, and a subjective dimension, which would include the question of citizen efficacy, the feeling of actually being able to act competently and having something to offer to the political community (Goul Andersen 2004).

In this article, we have not arrived at a grand model of scientific citizenship. Such a model was simply not empirically feasible with the items that we analysed: to achieve a well fitting model would require too many classes to yield a useful solution. Whether this reflects the complex reality of scientific citizenship, or whether it is an artefact of the survey data, we cannot confidently say. We might note that the survey items are quite varied in style and in content: they ask for self-reports of affective and behavioural attributes, and for subjective and objective levels of informedness. The knowledge 'quiz' items themselves have been identified by others as being of questionable validity for cross-national comparisons (e.g. Pardo & Calvo, 2004; Peters 2000). We might, then, fare better with a grand typology of citizenship with a set of items written specifically to test such a model, and we hope future Eurobarometer surveys will afford us the opportunity to develop and test our ideas empirically. Developing of a good set of indicators of scientific citizenship would entail more in-depth assessments of their content validity and transferability across national contexts. This would ideally involve both quantitative and qualitative approaches. For the former, we would want to investigate in what ways the relationship between the elements of scientific citizenship varied amongst countries, as well as the association between scientific citizenship and other indicators commonly used in PUS studies. For the latter, we would want to scrutinise the *social* significance of the survey items used to capture elements of scientific citizenship.

In the meantime, we have used a straightforward set of statistical analyses to try to shed light on what could perceivably be constituent dimensions of scientific citizenship and to examine their interaction. We conclude by tentatively suggesting that at least two main types of scientific citizenship can be identified: One group of citizens, in the top left corner of the correspondence plot, are likely to be both highly participative (vertical and horizontal) and high on competence. We could label this cluster 'involved' or perhaps 'mobilized' citizens. It is worth noting, that both the High+ and the High- clusters are located here, which seems to infer that the objective aspect of competence - textbook knowledge - is not an absolute prerequisite for action, rather, vertical participation appears to be associated with subjective competence (or self-confidence). Another group of citizens, at the right-hand side of the plot, might be labelled 'detached' citizens. This cluster of citizens do not get involved, neither horizontally nor vertically, and they appear to be neither subjectively nor objectively competent. Effectively, these citizens are marginalised in the knowledge society. It is a bit harder to try to name and distinguish between those in the middle of the plot. Relatively speaking, the 'horizontal only' class of participation is most closely associated with the Low ++ competence class, which is characterised by feeling poorly informed, even if they are somewhat interested and possess relatively higher levels of text-book knowledge. These citizens might in some way resemble what Miller (1983) has called the 'attentive' public for science, that is, people who are scientifically literate and rather interested, and who engage in active patterns of knowledge acquisition in terms of reading articles on science and talking to friends about science.

The main conclusion on the basis of the comparison between respondents' class membership in the competence model and the participation model, is that public participation and public competence concerning science are not 'poles apart', as one could be led to believe based on current polemics over PUS or PES approaches in science communication. On the contrary, the analyses clearly suggest that competence and participation are really two sides of the same coin; that these dimensions appear to mutually stimulate each other, and hence, that science communication activities might benefit from strategies that aim at advancing both. PUS at the crossroads, then, does not necessarily involve choosing one over the other. We have suggested that the notion of scientific citizenship could be a relevant inclusive framework for studying the relationship between science and citizens, as it recognises the importance of scientific competence while also arguing that the legitimacy of the knowledge society is dependent on citizens upholding, testing, confronting, and improving the system by means of civic participation in making decisions about science and technology.

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References

Almond, G. A. & Verba, S. (1963). The Civic Culture – Political Attitudes and Democracy in Five Nations. New Jersey: Princeton University Press.

Banthien, H., Jaspers, M. & Renner, A. (2003). *Governance of the European Research Area: The Role of Civil Society*. Brussels: European Commission.

Barber, B. (1984). *Strong Democracy – Participatory Politics for a New Age*. Berkeley: University of California Press.

Bartholomew, D. J., & Knott, M. (1999). *Latent Variable Models and Factor Analysis*. London: Arnold.

Bartholomew, D. J., Steele, F., Moustaki, I., & Galbraith, J. I. (2002). *The analysis and interpretation of multivariate data for social scientists*. London: Chapman & Hall/CRC.

Bauer, M. (2003). The vicissitudes of ’Public Understanding of Science’: from ’literacy’ to ’science in society’. In *Science meets Society*. Lisbon: Fundacâo Calouste Gulbenkian.

Mauer, M., Allum, N. & Miller, S. (2007). What can we learn from 25 years of PUS survey research? Liberating and expanding the agenda. In *Public Understanding of Science*, 16(1): 79-95.

Durant, J. R., Evans, G. A. & Thomas, G. P. 1989. The public understanding of science. In *Nature*, 340: 11-14.

Durant, J. R. (1999). Participatory Technology Assessment and the Democratic Model of the Public Understanding of Science. In *Science and Public Policy*, 26(5): 313-319.

Elam, M. & Bertilsson, M. (2003). Consuming, Engaging and Confronting Science – The Emerging Dimensions of Scientific Citizenship. *European Journal of Social Theory*, 6(2): 233-51.

Evans, G. & Durant, J. (1995). The relationship between knowledge and attitudes in the public understanding of science in Britain. *Public Understanding of Science*, 4, 57-74.

Gaskell, G., Stares, S., Allansdottir, A., Allum, N., Corchero, C., Fischler, C. et al. (2006). *Europeans and biotechnology in 2005: patterns and trends (final report on Eurobarometer 64.3)*: A report to the European Commission’s Directorate-General for Research.

Gibbons, M. (1999). Science's new social contract with society. In *Nature*, 402(6761): C81-C84.

Goul Andersen, J. (2004). *Et ganske levende demokrati*. Aarhus: Aarhus Universitetsforlag.

Hagendijk, R. P. (2004). The public understanding of science and public participation in regulated worlds. In *Minerva*, 42(1): 41-59.

Healey, P. (1999). Popularising science for the sake of the economy: the UK experience. In Miettinen, R. (ed.) *Biotechnology and public understanding of science – Proceedings of the*

UK-Nordic co-operative seminar, Helsinki October 25-27, 1998. Helsinki: Academy of Finland.

Horst, M. (2007). Public Expectations of Gene Therapy: Scientific Futures and their Performative Effects on Scientific Citizenship. In *Science, Technology and Human Values*, 32(2): 150-171.

Irwin, A. (2001). Constructing the scientific citizen: science and democracy in the biosciences. In *Public Understanding of Science*, 10(1): 1-18.

Jasanoff, S. (ed.) (2004). *States of Knowledge: the co-production of science and social order*. New York: Routledge.

Joss, S. & Durant, J. (eds.) (1995). *Public participation in science – The role of consensus conferences in Europe*. London: Science Museum.

Jöreskog, K. G., & Moustaki, I. (2001). Factor analysis of ordinal variables: a comparison of three approaches. In *Multivariate Behavioral Research*, 36: 347-387.

Kuha, J. (2004). AIC and BIC – Comparisons of Assumptions and Performance. *Sociological Methods and Research*, *33*(2), 188-229.

Lazarsfeld, P. F., & Henry, N. W. (1968). *Latent structure analysis*. Boston: Houghton Mifflin.

McKennell, A. C. (1979). Attitude scale construction. In C. A. O'Muircheartaigh & C. Payne (Eds.) *The analysis of survey data*. Chichester: John Wiley.

Michael, M. & Brown, N. (2005). Scientific Citizenships: Self-representations of Xenotransplantation's Publics. In *Science as Culture*, 14(1): 39-57.

Miller, J. D. (1983). *The American People and Science Policy: The role of public attitudes in the policy process*. NewYork: Pergamon Press.

Miller, J. D. (1998) The measurement of civic scientific literacy. *Public Understanding of Scinece*, 7, 203-223

Miller, J. D. & Kimmel, L. G. (2001). *Biomedical communications – purposes, audiences and strategies*. San Diego: Academic Press.

Miller, J. D. & Pardo, R. (2000). Civic scientific literacy and attitude to science and technology: a comparative analysis of the European Union, the United States, Japan, and Canada. In M. Dierkes & C. von Grote (Eds.), *Between understanding and trust: the public, science and technology*. Amsterdam: Harwood Academic Publishers.

Miller, S. (2001). Public understanding of science at the crossroads. In *Public Understanding of Science*, 10(1): 115-120.

Pardo, R. & Calvo, F. (2004). The cognitive dimension of public perceptions of science: methodological issues. *Public Understanding of Science*, 13, 203-227

Parry, G., Moyser, G. & Day, N. (1992). *Political participation and democracy in Britain*. Cambridge: Cambridge University Press.

Peters, H.P. (2000). From information to attitudes? Thoughts on the relationship between knowledge about science and technology and attitudes toward technologies. In M. Dierkes & C. von Grote (Eds.), *Between understanding and trust – the public, science and technology*. Amseterdam: Harwood Academic Publishers.

Putnam, R. D. (1995). Bowling Alone: America's Declining Social Capital – an interview with Robert Putnam. In *Journal of Democracy*, 6(1): 65-78.

Royal Society of London (1985). *The public understanding of science*. London: Royal Society.

Sandel, M. J. (1996). *Democracy's discontent - America in search of a public philosophy*. Cambridge: Harvard University Press.

Vermunt, J. K., & Magidson, J. (2005). *Technical Guide for Latent GOLD 4.0: Basic and Advanced*. Belmont Massachusetts: Statistical Innovations Inc.

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Table 1 Items capturing participation and competence in science

Survey question	*% responses*		
PARTICIPATION ITEMS			
How often do you...?			
Responses recoded: Regularly/occasionally/hardly ever into 'Yes', and Never into 'No'			
	Yes	No	Don't know
Read articles on science in newspapers, magazines or on the Internet	78.3	21.3	0.4
Talk with your friends about science and technology	70.8	28.7	0.5
Attend public meetings or debates about science or technology	28.4	71.0	0.6
Sign petitions or join street demonstrations about nuclear power, biotechnology or the environment	24.3	74.8	0.9

COMPETENCE ITEMS

Let us talk about those issues in the news which interest you. For each issue I read out, please tell me if you are very interested, moderately interested or not at all interested in it.

	Very interested	Moderately interested	Not at all interested	Don't know
New inventions and technologies	28.9	46.9	22.9	1.3
New scientific discoveries	28.7	46.6	23.1	1.6

I would like you to tell me for each of the following issues in the news if you feel very well informed, moderately well informed or poorly informed about it?

	Very well informed	Moderately well informed	Poorly informed	Don't know
New inventions and technologies	10.9	50.3	36.4	2.4
New scientific discoveries	9.7	48.8	39.1	2.4

Knowledge	% answering 9 or more items correctly	% answering less than 9 items correctly
Derived variable from responses to 13 statements about science and technology[7]	50.2	49.8

[7] The thirteen items are the following: (1) The Sun goes around the Earth; (2) The centre of the Earth is very hot; (3) The oxygen we breathe comes from plants; (4) Radioactive milk can be made safe by boiling it; (5) Electrons are smaller than atoms; (6) The continents on which we live have been moving for millions of years and will continue to move in the future; (7) It is the mother's genes that decide whether the baby is a boy or a girl; (8) The earliest humans lived at the same time as the dinosaurs; (9) Antibiotics kill viruses as well as bacteria; (10) Lasers work by focusing sound waves; (11) All radioactivity is man-made; (12) Human beings, as we know them today, developed from earlier species of animals; (13) It takes one month for the Earth to go around the Sun.

Table 2 Fit statistics for joint cross-national models of participation and competence

Model	L^2	d.f.	p (bootstrap)	AIC	BIC	% 2-way standardised marginal residuals >4: Overall	Conditional on country: Mean	Median	Minimum	Maximum
PARTICIPATION										
4 items, 2 classes	7,869	1,029	<0.001	5,811	-2,785	40.4	53.0	58.3	16.7	79.2
4 items, 3 classes	3,418	993	<0.001	1,432	-6,864	18.9	34.4	33.3	4.2	75.0
4 items, 4 classes	1,954	957	<0.001	40	-7,955	7.1	16.4	12.5	0.0	66.7
3 items, 2 classes	2,211	362	<0.001	1,487	-1,537	30.4	44.5	45.9	0.0	91.7
3 items, 3 classes	816	327	<0.001	162	-2,570	4.4	13.5	8.3	0.0	50.0
3 items, 4 classes	518	292	<0.001	-66	-2,505	1.5	5.7	0.0	0.0	41.7
COMPETENCE										
3 items, 2 classes	8,981	836	<0.001	7,309	325	47.3	57.0	61.9	19.0	90.5
3 items, 3 classes	5,988	799	<0.001	4,390	-2,285	35.7	45.8	52.4	0.0	81.0
3 items, 4 classes	3,877	762	<0.001	2,353	-4,013	22.4	31.9	28.6	4.8	71.4
3 items, 5 classes	2,787	725	<0.001	1,337	-4,720	14.8	21.1	14.3	0.0	57.1
3 items, 6 classes	2,279	688	<0.001	903	-4,845	6.5	13.4	9.5	0.0	52.4
3 items, 7 classes	1,952	651	<0.001	650	-4,788	5.4	7.6	4.8	0.0	28.6

Table 3 **Conditional and prior probabilities for a joint cross-national model of participation in science**

Item/response	Response probabilities for categories of items, conditional on class: **Horizontal & vertical**	**Horizontal only**	**Non-participative**
Read articles on science			
Yes	0.98	0.97	0.20
No	0.02	0.03	0.80
Talk with friends about science and technology			
Yes	0.99	0.80	0.13
No	0.01	0.20	0.87
Attend public meetings/debates about science or technology			
Yes	0.67	0.01	0.01
No	0.33	0.99	0.99
Estimated proportion in each class (pop. weighted)	0.42	0.33	0.25

Table 4 Estimated percentages in each class of participation, by country

	Horizontal & vertical	Horizontal only	Non-participative
Sweden	46	49	4
Finland	52	43	5
Iceland	30	63	7
Slovenia	40	53	8
Norway	38	54	8
Netherlands	25	64	11
Switzerland	60	29	11
Luxembourg	38	50	11
Estonia	30	57	13
Germany	55	31	14
Denmark	46	40	14
Croatia	47	37	16
Slovakia	51	31	18
Latvia	34	48	19
Belgium	36	46	19
Austria	68	13	19
Czech Republic	44	35	21
Cyprus	41	38	21
France	31	47	22
Lithuania	35	43	22
UK	33	43	24
Greece	76	0	24
Hungary	50	24	26
Poland	26	47	27
Ireland	46	26	28
Italy	54	17	29
Romania	28	39	33
Spain	43	19	38
Bulgaria	45	17	38
Turkey	36	23	41
Malta	26	31	43
Portugal	21	33	46

Table 5 Conditional and prior probabilities for a joint cross-national model of competence in science

Item/response	High+	High-	Mid+	Mid-	Low++	Low-
	Response probabilities for categories of items, conditional on class					
Interest in new scientific discoveries						
Very interested	1.00	0.85	0.14	0.18	0.12	0.00
Moderately interested	0.00	0.14	0.80	0.82	0.60	0.07
Not at all interested	0.00	0.01	0.06	0.00	0.28	0.93
Informedness about new scientific discoveries						
Very well informed	0.31	0.38	0.05	0.01	0.00	0.00
Moderately well informed	0.66	0.54	0.95	0.63	0.00	0.08
Poorly informed	0.02	0.08	0.00	0.37	1.00	0.92
Knowledge						
9 or more correct	0.91	0.27	0.73	0.14	0.69	0.08
less than 9 correct	0.10	0.73	0.27	0.86	0.31	0.92
Estimated proportion in each class (pop. weighted)	0.14	0.08	0.27	0.15	0.17	0.19

Table 6 Estimated percentages in each class of competence, by country

	High+	High-	Mid+	Mid-	Low++	Low-
Sweden	36	0	29	0	35	0
Netherlands	31	3	27	8	27	4
Germany	26	4	28	9	25	7
Norway	24	0	37	5	30	4
Denmark	23	1	30	2	37	7
France	22	13	37	9	9	9
Switzerland	22	12	35	9	18	5
Luxembourg	21	9	38	8	15	8
Iceland	19	6	16	15	38	6
Croatia	19	7	26	20	14	15
Hungary	19	2	27	12	22	18
Belgium	19	7	36	6	23	9
Finland	17	0	30	2	47	4
UK	15	8	34	8	22	14
Greece	14	27	23	20	0	16
Slovakia	13	0	24	13	34	16
Austria	12	9	24	17	22	16
Czech Republic	12	0	50	0	31	7
Ireland	11	9	20	21	18	21
Slovenia	10	7	47	0	31	5
Spain	8	9	17	24	21	20
Estonia	8	4	20	18	33	18
Italy	7	3	45	13	14	18
Poland	7	4	23	20	19	26
Malta	7	24	2	35	5	28
Latvia	6	4	7	46	9	28
Bulgaria	5	8	10	30	8	39
Romania	4	4	19	24	7	42
Portugal	3	4	16	37	1	39
Lithuania	1	1	11	26	18	43
Cyprus	0	51	3	34	0	12
Turkey	0	21	4	30	0	46

Figure 1 Bi-plot from correspondence analysis of measures of participation and competence