Executive Summary

The Netherlands is a major global producer of scientific knowledge that is valued in both the community of scientists and the world of applications of knowledge. The Dutch government wishes to formulate policies that are responsive to possible future developments that could influence scientific research. To assist in that goal, the Ministry of Education, Culture and Science (OC&W for its Dutch name), with the Ministry of Economic Affairs (EZ), asked RAND Europe to investigate the question, **"How should science policy in the near-term future be formulated in order to as well as possible accommodate and take advantage of anticipated developments so that the high quality and quantity of Dutch scientific research can be sustained?"**

In order to answer this question, RAND Europe designed, carried out and analyzed a series of four seminar games exploring different facets of the near-term future that could influence the course of scientific research. In this report, we describe the design and implementation of the games, report what happened in the games, and discuss the implications of the results for thinking about the future of Dutch scientific research.

DESIGN OF A SEMINAR GAME TO STUDY SCIENCE POLICY

Seminar gaming is a qualitative research methodology for understanding complex problems by asking groups in a highly structured hypothetical environment to develop policy options and explore their potential consequences. In general, a game is not aimed at solving a problem, but at better understanding it. By allowing interaction among different stakeholders with different backgrounds, experiences and responsibilities, the game makes it possible for them to better understand the different aspects of a problem. Gaming is an attractive tool for a "middle ground" of policy arenas, where the issues are too complex to analyze using precise quantitative tools, but are well-enough understood to create plausible models. In this middle ground, knowledgeable people may intelligently and rationally address the issues in the context of these structures. Science policy fits this description well.

There are three elements to a seminar game: the participants, the tasking and the scenario. Here, we shall briefly describe each of these elements as they were applied in this study.

Participants

Individual participants in a game are assigned to various teams representing important stakeholder groups. For science policy, we drew them primarily from the ranks of stakeholders in publicly-funded scientific research. These included policymakers, scholars (universities and research institutes), intermediary organizations, financiers of research and (public and private) users of scientific research. A total of 79 individuals each participated in one of four seminar games, held in April and May, 2001. One game took place in Amsterdam, two in Utrecht, and one in Nijmegen. (See *bijlage* 1 for a list of participants and *bijlage* 2 for the institutions they represented.) In each session, participants were divided into three teams of approximately equal size, representing "producers", "financiers" and "users" of scientific research. The assignment to teams was not systematic, except that we attempted to have each team approximately the same with respect to percentage of women, age distribution, and representativeness of different stakeholder groups. Participants were asked to assume the assigned role, even when this was not their natural position in science.

In addition to the playing participants, a control team of five RAND Europe staff, assisted by observers from OC&W and EZ, were present. The control team designed the game, directed the overall conduct of the game, chaired plenary and group sessions, and kept records of the game proceedings for later analysis.

Tasking

A seminar game, unlike brainstorming or expert meetings, is highly structured. Participants are asked to perform certain explicit tasks during the course of the game. The results of these tasks are the raw data that are used by the analyst to understand what happened during the game. The four seminar games of the present project all followed the same daily format, including the same explicit tasks. These are shown in figure S.1

Figure S.1: The Schedule of Events at a Seminar Game

Approx. time	Activity
08:30	Reception with coffee
09:00	Plenary session 1: Rules of the game, presentation of the scenario (advancing the calendar to 2008), and discussion of the scenario.
10:00	Team session 1: Discussion from team's perspective (producer, financier, user) of strengths, weaknesses, opportunities and threats ("SWOT analysis") of the scenario, leading to: **Task 1:** Make policy recommendations for improving the situation found in the scenario **Task 2:** Fill out a questionnaire comparing the scenario to the present day.
12:30	Lunch. During this time, the control team examined Task 1 and formulated policies that appeared to reflect a consensus of the three teams' recommendations.
13:30	Plenary session 2: Each team presented its recommendations and the control team presented its policy implementation plan. These were discussed.
15:00	Team session 2: After advancing the calendar to 2015, the teams discussed the consequences of the policy implementation plan. **Task 3:** Fill out the questionnaire, this time comparing the situation in 2015 to the scenario of 2008.
15:45	Plenary session 3: Summary discussion, featuring two major points: **Task 4:** The importance of having a ministry responsible for science policy. **Task 5:** (after returning the calendar to the present) Lessons to be learned for current science policy
17:00	Adjournment to a sherry hour and informal discussions.

Scenario

A seminar game is built around a "scenario", or detailed description of a situation, typically cast in the future, into which the participants are to insert themselves. Scenarios need not be very likely, but must be internally consistent and at least plausible. Because the scenario is specific, the discussion is forced to be on the basis of specific characteristics rather than being an abstract conversation of values or opinions. Because the scenario is distinctly different from the here-and-now, participants are detached from their current beliefs and policies.

We designed four different scenarios for this project; each one was used in a different game within the series. (The full texts of the scenarios are in *bijlage* 3.) The four scenarios each portrayed the scientific research arena in the Netherlands in the year

2008. They were systematically constructed by combining elements of three different dimensions that are important in considering science policy.

1. **Individuals vs. groups.** Science may be thought of as the effort of individual researchers or as a coordinated team effort. In designing the scenarios, we had one pair with an individual focus and one pair with a group focus. The individual-focus scenarios emphasized the autonomy of the individual researcher in determining research methods and topics. Science was structured in a traditional disciplinary sense. In the group-focus scenarios, there was a greater emphasis on team work; research careers were to be found working within multidisciplinary teams. Instead of the traditional disciplines as the organizing basis of scientific establishments, multidisciplinary units were the building blocks of institutions.
2. **Centralized vs. decentralized.** The direction of scientific research may be dictated by centralized or diffuse responsibility. One pair of scenarios had a centralized focus and one pair had a decentralized focus. In the centralized-focus scenarios, major themes for publicly-funded research were dictated by a top-down governmental structure; the work of research institutions was coordinated in a larger effort. In the decentralized-focus scenarios, research institutions competed among each other, and funding was on the basis of quality indicators.
3. **International integration vs. country competition.** While some degree of internationalization is inevitable between now and the year 2008, the extent of integration within the world of scientific research is uncertain. One pair of scenarios portrayed a world that was heavily internationalized, while the other pair had limited internationalization. In the full-internationalization scenarios, many of the functions of national scientific management had been turned over to international bodies such as the European Science Foundation (ESF). This was accompanied by a greater mobility of researchers across national boundaries, by increased international public-private research, and by English being adopted across Europe as the language of science. In the limited-internationalization scenarios, nations still competed for research honors, individual national management bodies remained strong, and cross-national migration of researchers was more limited. English was the scientific language in the Netherlands and Scandinavia.

The three dimensions can be combined to form eight different scenario-types, which fall into two distinct sets. We selected the set of four scenario-types that seemed the more plausible and used them to build four scenarios. Each scenario was given a name that suggested its nature.

- ***In de voetsporen van Van Leeuwenhoek* [In the footsteps of Van Leeuwenhoek].** This scenario had an individual-focus, a centralized-focus and limited internationalization. The name refers to the 17th century Dutch scientist and inventor of the microscope, who single-handedly made his scientific contributions as almost a by-product of his career in the Delft cloth industry (an industry very important to the economic well-being of Holland). In this scenario, Dutch scientific research is a "niche player," seeking highly defined rather than global opportunities for excellence; individual researchers chase the Nobel Prize and other rewards within these limited domains.
- **Champions' Leagues of Research.** This scenario had an individual-focus, a decentralized-focus, and full internationalization. The name refers on the one hand to the medieval international Hanseatic League of commercial cities and on the other to sports competitions in different sports, where the competition is created in order to mutually benefit all of the competitors. In this scenario, multinational coalitions of top research institutions form for as long as it is advantageous to maintain the coalition. Research themes are chosen by a competitive process ("let the winners choose"), and mobility is on an individual basis.
- **CAESAR (Coordinated Advanced European Science Area for Research).** This scenario had a group-focus, a centralized-focus and full internationalization. The name reflects the almost obligatory use of acronyms in European Commission-supported research and the dominance of the Commission in the scenario; it is also an aggrandizement of the "European Research Area" of the Sixth Framework. The scenario extends the direction currently being taken by EC-supported research, including the existence of relatively stable multi-national coalitions on multidisciplinary themes determined by the Commission. Within these coalitions, researchers frequently move from country to country.
- ***BV Onderzoek Nederland* [Dutch Research, Inc.].** This scenario had a group-focus, a decentralized focus and limited internationalization. The name is largely self-explanatory, and reflects an extension of the *poldermodel* of governance to the scientific research sector. The Dutch governmental science policy rewards the winners of competition among multidisciplinary Dutch research teams, and assists these winners in their further competition in the international marketplace.

Each scenario was built according to a common framework. First, certain common characteristics among all scenarios (e.g., population growth and demographic change) were presented; these are characteristics of 2008 that are almost certain to be true. The three dimensions of individual/group, centralized/decentralized and full internationalization/limited internationalization were presented in terms of their effect on the funding and management of research, on the number and nature of research institutions, on the national and international relationships among research institutions, and on some survey data (taken in 2000 and 2008) of the attitudes of researchers towards their jobs.

After the presentation of the scenarios, participants were given the opportunity to ask clarifying questions or debate some of the features of the scenarios. In these discussions, there were few serious challenges to the plausibility of the scenarios, and participants could proceed with the remainder of the day's activities inside the world of the presented scenario.

FINDINGS

The amount of information that arose from this project is vast and complicated. In the main body of the report, we provide results for each of the tasks of the game—that is, the policy recommendations for 2008, the questionnaires for 2008 and 2015, and the summary discussion. These are then presented in terms of twenty major key issues for science policy, shown in Figure S.2. Finally, the results are synthesized in terms of three propositions that capture the results of the game. In this executive summary, we concentrate on the synthesis of results.

Figure S.2: Twenty major issues for science policy

1:	How can public investment in scientific research be better coordinated?
2:	How can both individual excellence and group effort in scientific research be supported?
3:	What are the features of a functioning system of individual responsibility for research results? Can quality indicators be employed for this use?
4:	In what manner can it be determined how many universities and faculty departments are needed, and how can these be allocated?
5:	What is the appropriate role for intermediary organizations (such as the national science foundation)?
6:	What is the right level of financing of scientific research for the optimal functioning of the knowledge economy, and what is the allocation of responsibility for this financing between the public and private sectors?
7:	How can stable financing of scientific research be established while maintaining an emphasis on quality, flexibility, multidisciplinarity and the maintenance of fundamental research?
8:	Must there be more variety in the sources of financing, or should there be more simplification? What is the right division of financing among the three money streams? How does this relate to the goals of the national innovation system?
9:	How can researchers and their efforts be allocated over fundamental research, applied research and education?
10:	How much and which research is really necessary? How does one choose?
11:	How can contract research be financed without compromising the objectivity of scientific research?
12:	Is scientific research best conducted as monodisciplinary or multidisciplinary work?
13:	How can the public image of scientific research be improved, so that its importance, especially in the higher levels of decisionmaking, is given due recognition? What role can the scientific community play in this regard?
14:	How can internationalization of research be of benefit to the Netherlands? How should the Netherlands position itself in the global scientific research community?
15:	What is the influence of internationalization on the way in which Dutch research institutions work with each other and with foreign research institutions? What should policymakers do in this regard?
16:	How can the best talent be convinced to undertake scientific research careers?
17:	How can good researchers be encouraged and their motivations sustained?
18:	What steps should be taken in secondary education with an eye towards the needs of scientific research?
19:	What is the best way to implement the Bachelors-Masters model of university education from the perspective of the quality of scientific research?
20:	Are there adaptations needed in the policy and management of educational institutions?

Analysis of the extensive results of the series of four seminar games yielded three propositions that we believe integrate much of the diverse information. They are:

1. No revolutionary changes are needed to the Dutch policy vision of scientific research. The objectives and basic ambitions of Dutch scientific policy are viewed

as good, but there are (sometimes major) ways in which the statement and implementation of policy could be improved.

2. There are two independent values driving the need for scientific research—science as a tool for improving society (the instrumental value of science) and scientific knowledge as an inherent good (the non-instrumental value of science). Seminar game participants subscribe to both of these values and are uncomfortable with having to trade off one against the other. In situations where such tradeoffs are perceived, the people feel stress. This stress, however, is not directly expressed in terms of the values, but takes on a number of other forms, some of which are major elements of the policy debate.
3. A lot of the criticism of current science policies results from anxiety arising from uncertainty and confusion about what these policies are and how they are implemented. This uncertainty and confusion can be attributed to a lack of clarity, coordination and transparency at all levels of decisionmaking regarding science policy.

No revolutionary changes

It is almost universally recognized that science policy is an important area of government responsibility, even while there are intense debates about how that responsibility should be carried out. Policymakers must take care that there are effective mechanisms for:

- setting priorities for the direction science takes,
- allocating funds in line with these priorities,
- making long-term plans, and
- providing an efficient accounting and administration system.

In short, these translate into optimizing governance of the science system. In each of the four seminar games, we asked as a closing question whether there needed to be a Ministry of Science, followed up with a discussion about whether that ministry's portfolio needed to include education. The answer to the first part was a universal and firm "yes," and the affirmation of the link between science and education was almost equally strong, especially as it concerns higher education and to a lesser extent secondary education.

There was also a consensus about what the objectives of science policy should be. This consensus can be summarized as a set of basic ambitions:

1. prioritizing policy to produce an overall high quality of research in the Netherlands,
2. having a funding system that leaves no major aspect of research seriously underfunded,
3. promoting autonomy and responsibility among researchers,
4. facilitating the presence of the Netherlands as a major actor in the international research arena, and
5. ensuring an educational infrastructure that sustains high-quality research.

How best to realize these ambitions, however, was often the topic of serious debate among the participants.

Our conclusion from examining where consensus and disagreement were to be found in the seminar game discussions is that the science policy system in the Netherlands is not at present in need of revolutionary change. By "revolutionary change" we mean a rethinking of the vision and mission of science policy in terms of the ambitions expressed immediately above. This does not mean, however, that OC&W can rest comfortably upon its laurels. Implementation plans for each of the basic ambitions can be improved, and proactive adjustments to policy in anticipation of changes in the environment are always a good idea.

Evidence for this conclusion may be found in the reactions of the players to the scenarios. For each of the scenarios, we pushed one or more facets of present policy to an "extreme" (but still realistic) position. For example, in the centralized-focus scenarios, societal goals drove the allocation of research funding. Or, in the full internationalization scenarios, the Netherlands had surrendered a lot of policymaking power to Brussels. While the participants were generally favorably inclined to the scenarios of 2008, they reacted to the extreme positions taken by recommending steps to move back towards present policies. For example, in the discussions regarding the personal accountability of researchers, the versions of quality indicators posed in the decentralized-focus scenarios were viewed as too mechanical and not capable of reflecting nuances in quality. When the issue of reducing the number of universities supporting certain disciplines was raised, fear of overconcentration in too few institutions was expressed. Major changes to the current set of intermediary organizations were viewed with suspicion, especially if international organizations such as the ESF were to replace their Dutch counterparts. As a last example, in considering how to keep good researchers committed, neither intense individual competition, as in the Van Leeuwenhoek scenario, nor stable teams, as in the group-focus scenarios, were viewed as good changes to the current situation. A middle road of group-based research, but where the groups changed over time in response to interests and demands, was preferred.

The afternoon sessions of the game provide a final piece of evidence regarding the overall stability of the current vision of scientific research. Once the players' recommendations to correct the weaknesses and threats of the 2008 scenario were implemented, thus making the situation more balanced, then the views of 2015 were more clearly positive on all dimensions, and there were no differences in the 2015 questionnaire among scenarios.

Two values of science: the desire to have it all

There are two distinct values of scientific research. First is the contribution of research in making society better—we will call this "instrumental value." It is important to emphasize that instrumental value can arise from basic or applied research. Second is the non-instrumental value of scientific research. That is, scientific research has value as a good onto itself, as a part of cultural heritage, or even as a moral imperative to improve knowledge. Just as a Rembrandt painting or a Beethoven symphony does not have to be "useful" to have value, so can an elegant theory of the role of group portraits in the Golden Age of the Netherlands or a careful analysis of the Fifth Symphony be admired, treasured and even marketed. Here, it is important to emphasize that any individual piece of scientific research may have both instrumental and non-instrumental value—the two are far from mutually exclusive. Therefore, non-instrumental value can also arise from basic or applied research. Both of these values are important to most people, including the great majority of game participants, and any attempt to force people to choose between them would be met with resistance; especially as it is often possible to combine the two within one research effort. Nonetheless, the realities of policy choices in science are that sometimes each value requires its own set of policy measures, and these measures may not always be entirely in harmony. Thus, there can arise situations in which policy sometimes favors or appears to favor one of these values over the other. In these situations of conflict between two desirable values, stress is created.

In our view, this stress is generally not recognized as a tension between instrumental and non-instrumental values, and instead is manifested in other forms. A number of these other forms are commonly expressed in debates on science policy, including during our seminar games.

- **basic vs. applied research.** This is a very common debate—one that we, among many others, believe is based upon a false dichotomy. As is almost always pointed out in such debates, the distinction is fuzzy at best. We believe that this debate is a reflection of an assumption—equally false as we argued immediately above—that basic scientific research has non-instrumental value and applied scientific research has instrumental value. As a result, it is believed—certainly in our seminar games and probably more generally—that an overemphasis on applied scientific research puts the non-instrumental value of science at risk. By association, multidisciplinary research, because it is viewed as largely applied, is seen weighted towards instrumental value while monodisciplinary research, viewed as largely basic, is seen as weighted towards non-instrumental value.
- **alpha (humanities) vs. beta ("hard sciences") vs. gamma (social sciences).** This distinction made in Dutch universities has a basis in fact, but is exaggerated in the public debate. All are properly scientific research, although alpha disciplines are sometimes thought of as not science at all. As is recognized in the Netherlands if not everywhere, this is not true; art historians are just as bound to the basic canons of scientific evidence as are biochemists, and astronomers are no more capable of experimentally manipulating their objects of study than are Latinists. In the Netherlands, although the alpha disciplines are accepted as science, the beta and gamma sciences are more thought of as providing either non-instrumental value (insights into the physical world or the human condition) or instrumental value (transformation of science into technology or human engineering), while the alpha sciences are more thought of as purely non-instrumental, and in any event requiring a different set of policies. As a consequence, the tensions arising between instrumental and non-instrumental values are sometimes expressed as conflicts among the different types of science.
- **autonomy vs. accountability.** This distinction is significant and real, but also has components that are associated with the tension between the two values of science. Autonomy is identified with non-instrumental value as the liberty of the scientist to pursue whatever research he or she thinks is valuable. Accountability is identified with instrumental value as the obligation of the scientist to provide

> value for money to the society that funds the research. Even allegedly "pure basic" research can fall victim to this dichotomy when funding agencies award research grants on the basis of the ability of the researcher to specify in detail the anticipated results of the research. Faced with such standards of accountability, research scientists become very risk-averse (i.e., less autonomous) in their work, and scientific progress as a whole is impeded.

The existence of the two independent values of scientific research finds clear support in the factor analysis of the cognitive dimensions comparing the scenarios of 2008 with the situation in 2001 (see section 3.3 and *bijlage* 5). The analysis revealed four independent cognitive dimensions, of which two (2008A="science as the servant of society" and 2008D="science as an intrinsic value") are instrumental and non-instrumental values of scientific research, respectively. Participants found instrumental value better served in 2008 than in 2001, but non-instrumental value worse in 2008 than in 2001. That these differences crossed over all scenario boundaries indicates that the beliefs were some consequence of the "constant" aspects of the scenarios, all of which included a greater role for thematic research (although the themes were generated from different sources) and some diminution of the fixed allocation of support to institutions.

The tension between the two values was also present in discussions about quality indicators for research. Quality in non-instrumental contexts is measured in terms of methodological soundness, while quality in instrumental contexts is measured in terms of applicable results. In centralized-focus scenarios where societal values (and hence instrumental values) drove the choice of research topics, participants reacted sharply and critically. However, because the participants shared the desire to have scientific research with high instrumental value, it was difficult for them to capture what it was that bothered them. As a result, criticisms were heard in terms of loss of autonomy of the researchers, threats to the sustainability of basic research and the disappearance of research topics. But, because themes were societally driven (reflecting basic instrumental scientific values), this research was still viewed as having scientific objectivity unless the private sector was viewed as the dominant actor in determining what research was conducted. On the other hand, in scenarios where scientific research was characterized by individual effort and a high degree of autonomy (hence, supposedly, non-instrumental values), there was concern that researchers might retreat into an isolated world of their own.

Uncertainty causes anxiety.

Clarity about the processes that drive policy decisions is as important in creating social support for those decisions as their distributional consequences. A well-established social psychological finding is that obtaining agreement about the rules that determine outcomes can induce people to accept those outcomes that might be less beneficial than they would have desired. Indeed, this type of thinking is at the core of the so-called *poldermodel*.

Although there was no call for revolutionary reformulation of the vision driving science policy, there was in the seminar games a considerable call for major changes in how this policy was implemented. In the discussions, it was clear that this call was in large part a result of lack of clarity and sometimes confusion about how the present system actually works and an absence of adequate coordination among different agencies responsible for different parts of policy. In other words, the procedures were not clear. The anxiety and uncertainty expressed by the seminar participants cannot be attributed to their lack of knowledge or their inexperience. More specifically, the seminar game participants expressed dissatisfaction with the ways in which research budgets were allocated and how research themes were chosen. This dissatisfaction was sometimes a disagreement among participants about how things were done, or could be a statement about not knowing how it was done. Although there was dissatisfaction with the present situation, recommendations for change were sometimes difficult for the game participants to construct.

The lack of transparency and coordination in the implementation of science policy is a result of the evolutionary path that resulted in the current system. This system makes effective and efficient management in either top-down or bottom-up directions problematic. The demand for a new vision of management, as the participants put it, is oriented towards more transparency. In this way, transparency and coordination are a necessary part of the management vision, that is, major drivers of the how to think about science policy.

Implicit evidence from the seminar games regarding these general points comes from the general tone of the discussions and the nature of the recommendations to adjust the 2008 scenarios. Explicit evidence comes from the discussions about coordination among various governmental ministries and agencies; here, the lack of clarity was the dominant topic of discussion. In discussions regarding the roles of intermediary organizations, there was a considerable debate about how these roles have shifted over time, resulting in no stability or predictability about what these roles might be in the future. In discussions about the level of financing, the reasoning behind the relative contributions of the public and private sector was unclear to the participants, so there was no consensus about what the right amount might be. The entire discussion about having stable financing for scientific research was a call for clarity. Improved communication about what science is and what science does was at the core of the discussion about the public image of scientific research; this was also viewed as the most important element in obtaining the best qualified people to become and remain scientific researchers.

ISSUE POINTS FOR THINKING ABOUT POLICY ABOUT SCIENTIFIC RESEARCH

The propositions arising from the conduct of the seminar game have implications for the major issue points that arise in public discussions of the future of scientific research. In the final chapter of the report, we introduce considerations that arose from the seminar games for seven such issue points:

- Balancing the autonomy and accountability of researchers
- Choosing research themes and allocating the research budget
- Promoting research as a career choice
- Informing the knowledge marketplace
- Defining the national innovation system
- Educating new researchers
- Accommodating the internationalization of research

These considerations extend existing discussions, sometimes in (deliberately) provocative ways. In the main body of the report, we briefly summarize the current state of discussions on the issue points and describe how they were addressed during the seminar games. Here, we present a statement of the issues and reformulations for the public discussion on science policy that emerge from our analysis of the games.

Balancing the autonomy and accountability of researchers

"Academic freedom" is a traditional value that must be preserved; on the other hand, researchers must be accountable if their work is to be subsidized by society. This balance translates into measuring the quality of research—research of high quality should be supported and flourishes in an atmosphere of freedom, while research of poor quality does not merit financing and is an abuse of freedom.

Measurement of quality can be done in many ways. Difficulties emerge as there are competing pressures between "top-down" and "bottom-up," as the unit of research can shift from monodisciplinary to multidisciplinary, and as efforts are made to standardize assessment through uniform quality indicators. For the first of these issues, considerable advance has been made by the recent work of Van Bemmel and others; a substantial part of that position was supported by the seminar game participants, and we concur with their recommendation for internal assessments supplemented by periodic external visitations. The basis of these assessments, however, can be further refined.

It is argued that because traditional quality indicators are based upon disciplines, the assessment of multidisciplines can be problematic. We rebut this argument by pointing out that multidisciplines, as they mature, take on all the trappings of disciplines. Examples are the multidisciplines of health services research, policy analysis, women's studies and safety systems. In each of these, the multidiscipline has produced a professional society, peer-reviewed journals, textbooks, and eventually a tradition. These are the ingredients for the assessment of scientific quality, and therefore multidisciplines may be assessed in much the same manner as disciplines.

Uniform quality indicators are popular in the discussion of research accountability, but run into the difficulty that "one size does not fit all". That is, it can be argued that the criteria for assessing the quality of researchers in one field, one nation, or even one institution are unique. We agree that indicators are dependent on characteristics of a research field; for each discipline, a measure of quality may differ in addressing the importance and extent of the number or size of published documents, the form of dissemination, the breadth and depth of confirmable references to research products or the manifest applications of research. However, within a discipline (or multidiscipline), it should be possible to measure performance upon a common metric, across institutions within a country and—certainly within developed countries—across national boundaries as well. This argues for a uniform set of quality indicators per discipline, and given that the members of this discipline will be held accountable to the indicators and compete on the basis of these indicators, they are in the best position to develop them. Such a standard quality metric does not mean that all research institutions are judged the same, however. A researcher or an institution may negotiate where on the metric it aspires to be, on the basis of reputation, ambitions, and available resources. In this way, based upon clear and consensually derived measures of quality, each researcher and institution can have clear objectives tailored to individual situations.

Choosing research themes and allocating the research budget

Closely related to autonomy and accountability are the choices of what research to conduct and how much to pay for that research. These are the two major ways in which the path of scientific research is directed (or set free from direction). The public discussion here centers on the extent to which societal values should drive the direction of research and how public money for research should be allocated within the traditional three money streams of—roughly—unrestricted institutional funding, themed funding and contracted research.

It is here that the distinction between fundamental research and applied research holds prominence. As we stated earlier, this is not always the must useful distinction—instrumental research and non-instrumental research may each be fundamental, applied, or a combination of the two. And both of these types of research are valued and should be supported. For the support of both instrumental and non-instrumental research, there is a manifest preference within the seminar games for "bottom-up" choice processes in selecting research topics, even when themes are decided by a "top-down" selection process. That is, as much as possible, decisions should devolve to a level as close to the actual researchers as reasonable. This is consistent with the present practice, including the use of platforms and various commissions and advisory boards. However, the clarity of the processes of these agencies and the coordination among them might be improved upon. If the balance between instrumental and non-instrumental research should become out of equilibrium, there are a number of mechanisms that might be considered.

Research budgets are not only a function of research themes, but also of the quality of research. Current practice for budgetary allocations are based in large part upon historical practice. This has the advantage of reducing uncertainty, even though it might be inequitable or not responsive to thematic priorities. An alternative allocation system would be to allocate research budgets on the basis of the assessed quality of research institutions or programs within institutions (sometimes referred to as "dynamic budgeting"). This, however, might introduce greater uncertainty into the research world and would have to be approached with great care to avoid creating imbalances or leaving some research areas underfunded to the point of extinction. In our view, the introduction of the type of quality measurements we referred to above—specific to research area—would ease the acceptability of at least some research funding being dynamically-based.

Finally, there is the often-discussed issue of the appropriate weight of the three money streams in supporting scientific research. This is related to the notion of dynamically-based budgeting. As we see it, the first money stream serves the function of maintaining predictability, and is therefore not a good candidate for conversion to dynamic-based budgeting, although evolutionary change in response to quality measurement provides incentives to improve the quality of research. But this stream should not be dependent upon top-down choices among research themes. Moreover, this money stream presently accounts for the majority of research expenditures, and any major change away from this would be perceived as revolutionary and undesirable. The second and third money streams, where there is more active competition on the basis of quality, may be said to already be largely dynamically-based and responsive to the knowledge market (see below).

Promoting research as a career choice

As the importance of scientific knowledge for sustaining and improving the quality of life increases, ensuring the supply of scientific researchers becomes more critical. It is important that research as a career be attractive to the top talent, and that the talent be used in an efficient manner. Promising careers must be supported as an investment, and nonproductive people must not be allowed to impede the career progress of producers.

As part of this discussion, the tradition of lifetime tenure has come under fire. While most observers acknowledge that tenure does result in abuses and inequities, abolishing it would be both revolutionary and unsettling. Therefore, any consideration of altering the principle of tenure where it now exists should be approached with great caution, and a substitute policy should only be adopted if it is clear and based upon transparent quality standards, maintains a form of job security corresponding to what is available in other societal sectors, and has wide acceptance from all relevant stakeholders.

Human resources management is a specialization that has emerged as useful in many public and private sectors, and may well be of value in the research sector as well. At present, management of universities and research institutes is typically done by researchers who by virtue of successful research have risen to management positions; it is not at all self-evident that the same talents and skills that lead to research productivity also lead to excellence in managing the research careers of other researchers. Professional human resources managers can serve as intermediaries who can improve upon the advice researchers obtain on their optimal career paths while also ensuring that the research institutions sustain the quantity, quality and diversity of researchers needed.

Researchers have traditionally been mobile relative to other professionals with comparable amounts of training and expertise. Even so, as this mobility becomes more international, issues involving the maintenance of social benefits such as health care and pensions can become relevant in attracting and maintaining top talent to the research world. These issues are of course not limited to researchers, but are real and relevant. For example, European Commission programs for the exchange of researchers within the EU (e.g., the Marie Curie Fellowships) do not provide for pension benefits, much less specify which country is responsible for maintaining the pension benefit account. While there is talk of EU coordination of such benefits in the future, that future is presently very uncertain from the perspective of the researchers. In this instance, it is worthwhile to consider the American "TIAA-CREF" profession-based pension system, which enrolls researchers throughout their careers as they successively work at many different institutions in many different states.

Informing the knowledge marketplace

It used to be said that "knowledge is power." Not only has that adage been proven time and again, but the role of knowledge has expanded. Now, knowledge is often thought of as a commodity, which means that we speak of a knowledge market, and public discussion is about how this market can be made efficient and equitable. Like all marketplaces, the knowledge marketplace requires open information, so that it makes sense to think about the knowledge of knowledge. Incomplete or inaccurate information can lead to market failures, which can translate into misplaced research priorities, duplicative efforts, and the neglect of some research domains.

The traditional means of dissemination of scientific knowledge are increasingly unsatisfactory in this new conceptualization of knowledge. Scientific literature is uni-directional from producer to user, has an inherent time delay, and tends to be within disciplinary stovepipes. Knowledge about knowledge could be enhanced by the existence of a publicly-available, detailed database containing information about scientific research. Such a database would facilitate the coordination among financiers, users and producers of research, resulting in the demand for research being more easily met and the supply being more easily accessed. Such databases are in various stages of development in many countries, including the Netherlands; most of these, however, have serious limitations. Eventually, they will have to be multinational, but even in the short-term, a Dutch national research database could be of benefit by providing integral oversight and merits serious consideration.

An efficient knowledge marketplace requires information about the costs of knowledge production. While institutions dedicated to research have accounting systems that can allocate the effort of researchers to their various research projects, institutions (principally universities) that mix functions (research and education) are not as clear. In universities, it is often difficult to determine how many hours a professor spends working, much less how many of those hours are devoted to research vs. teaching. Because research at universities is partially supported by direct research funding and partially supported by staff salaries not separable into a research percentage, the actual cost of research (and the possible subsidy of research by funding nominally addressed to other purposes) is not fully known. Developing a means of understanding the true costs of research production seems to be an effort that could lead to improving the knowledge marketplace.

Defining the national innovation system

The term "National Innovation System" (NIS) is often heard now, although its existence was barely acknowledged until recently. Like Molière's *bourgeois gentilhomme* who was not aware that he spoke in prose, there is not full awareness in the Netherlands of what the NIS is, what its goals are, and how it relates to the rest of science policy. It refers to a programmatic effort on the part of a country to direct science and technology towards new ways of achieving societal goals.

Although almost by definition an expression of the instrumental value of science, it is widely recognized that a successful NIS is dependent upon fostering a significant cadre of scientific investigators whose orientation might be decidedly non-instrumental. In today's complicated world, throwing money directly at a specific problem might not be the best way to solve that problem. In what is almost a paradox, investing to a minor extent in serendipity has proven to be a beneficial strategy.

Because the responsibility for managing the NIS is not only multidepartmental within government but quintessentially public/private, the issue here is not only one of clarity, but also one of explicit coordination. Scientific knowledge is the starting point of the chain of development of new goods and services; after the science has been done, there remain matters of translating the science into technology and eventually producing and disseminating societal applications ranging from infrastructure to consumer products to ways in which citizens think about the world. While this production chain is linear, the thinking behind it, including the conceptualization of a NIS, is not. The flow of policies and the supply and demand of ideas that constitutes the NIS goes in all directions among the elements of this chain. Indeed, some speak of the NIS as dealing with innovation cycles rather than chains; our own preference in this regard is to think instead of innovation networks. This, in turn, means that from the perspective of science, the key requirement for managing the NIS is coordination among its various components.

Coordination means that there should be more explicit consideration of defining the relative responsibility of the public and private sectors in generating innovative results of science and technology. The choice of research themes is driven by an NIS policy, which has not always been transparent. Moreover, whatever that policy is, it must maintain flexibility in order that innovation is not constrained.

How the NIS is thought of also plays a role in determining how much investment in research and development is made in the Netherlands and the relative importance of the monodisciplinary and multidisciplinary components of that research. As scientific research became increasingly internationalized, care must be taken that the objectives of the Dutch NIS are supported.

Educating new researchers

An adage adopted as a starting point for discussions about science policy is "science is what scientists do." Like some of the adages of the American baseball player and coach Yogi Berra or his Dutch football counterpart Johan Cruyff, there is more than meets the eye in such a simple statement. Here, it carries the immediate implication that science is dependent upon scientists; therefore, it is dependent upon a steady and adequate supply of new researchers. As we said above, during the final session of each of the seminar games, there was support for maintaining the link between science and education policy in a common ministry, largely but certainly not exclusively for this reason.

In Dutch universities, research and education are strongly linked, and this is viewed as a strength in the system. However, there is uncertainty how this linkage will be influenced by the shift to a Bachelors-Masters (BaMa) system of higher education. BaMa is generally viewed as leading towards more multidisciplinarity in higher education, and while this has benefits, it is not an unmixed blessing. The goal of higher education is the development of sophisticated levels of thinking that may be applied to both researchers and professionals (physicians, engineers, educators, lawyers, etc.) who are more users of scientific research than producers. Indeed, only a small percentage of university graduates will pursue a career as a researcher. This leads to a dilemma. While the multidisciplinarity and flexibility of the BaMa system might be beneficial for the majority of students, it might have negative effects for the future researcher. More specifically, the demands of research require a depth of knowledge in method and content that might not be available in a multidisciplinary curriculum. Thus, from the perspective of educating future researchers, discussions regarding BaMa or any other system of higher education should take into consideration the need for researchers even in multidisciplinary fields to have a solid disciplinary base upon which to stand. An implication of this perspective is that higher education needs to be able to accommodate both monodisciplinary and multidisciplinary studies at beginning, intermediate, and advanced levels.

Accommodating the internationalization of research

Internationalization is inevitable, and the internationalization of research, for example in the form of the emerging European Research Area, is one of the leading edges of the phenomenon. There exist international scientific societies for almost every discipline and multidiscipline. Because English has become the scientific *lingua* *franca*, a substantial percentage of Dutch Ph.D. dissertations (not to mention journal publications and books) are written in English; some Dutch universities will shortly adopt English as the default language of instruction. Only the pace and the specific form of internationalization are subject to discussion and manipulation.

Many of the important issues regarding internationalization in general, such as matters of immigration laws, brain drain (both out of and into the Netherlands) and integration policy, apply to scientific research, but were beyond the scope of the present project and not addressed in the seminar games. We have also touched earlier upon some issues related to internationalization, in the discussions on promoting research careers, informing the knowledge marketplace and defining the Dutch NIS. Here, we concentrate on international aspects of the conduct and financing of research.

The pace of the internationalization of scientific research is not something that is directly controllable by anyone, and it could arise that this pace is too slow for Dutch interests. In such a case, consideration should be made to hastening the process by entering into bilateral or multilateral agreements regarding resource sharing, exchange of research personnel, and allocation of research themes with like-minded nations, including those sharing borders with the Netherlands and the Scandinavian countries. This might begin, for example, by capitalizing on extant collaborations such as the development of new technologies for promoting environmental sustainability or studies of Germanic languages.

Even though the Dutch are potentially beneficiaries of internationalization, there are potential pitfalls. There are a number of potential threats to the health of Dutch research that could come about if scientific research themes were chosen and research funded through the auspices of the European Science Foundation or some comparable agency. These threats include the exclusion of Dutch-specific scientific interests (including both cultural heritage research areas and NIS-relevant areas) and the use of scientific research funds as another means of cross-subsidy of less-affluent EU regions. These threats can be guarded against in part by a strong and aware Dutch influence in the international scientific arena (as already exists), but even more by defining the competencies of international scientific agencies in such a manner that they never become monopolistic, but leave adequate room for local autonomy. In practical terms, this means that the equivalent of what is now the "second money stream" of Dutch scientific research financing might best be left largely in Dutch hands.

CONCLUSION

The three propositions summarizing the results of the seminar games—namely that there is no call for revolutionary changes in the vision of scientific research, that both instrumental and non-instrumental research should be fully nurtured, and that uncertainty due to a lack of transparency or coordination is a root cause of dissatisfaction with the system—do not lead towards either more or less centralization, more or less group-oriented research work, more or less thematically-oriented research or more or less internationalization. Within these propositions, any of these policy directions could be successfully taken, if the principles involved were clear, the policies had consensual support, there was adequate flexibility to accommodate both mainstream and some marginal research themes, and the independence and objectivity necessary for scientific research was sustained. We have presented, in the context of some of the major issues regarding the future of scientific research in the Netherlands, how these propositions might be incorporated into thinking about policy.

Thought of in this way, the propositions define guidelines for science policy that include making it faithful to its roots, flexible and comprehensive, and transparent and coherent. Specific policies at all levels, as instruments for the implementation of the vision, should be tested against the guidelines as so defined.