Round Table
Shaping the 21st Century
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Will Mathematics and the Mathematicians be able to contribute essentially in shaping the future?

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Let me first pose 3 questions to the audience, in an increasing "order
of seriousness".

1) Are you really interested in shaping the 21st century?
I doubt that, for most of the mathematicians, an honest answer would be "yes".
But some are, maybe even quite the important ones, as for example the
organisers of this conference. And some others will just answer: "Why not?" - as long as this answer does not have serious consequences. But our basic assumption for the rest of this discussion is a strictly positive answer to the first question.
2) Would you expect a young woman or a young man determined to shape the 21st century to choose mathematics as main subject?
And, even more serious
3) Assume, your daughter/son is very much interested in shaping her/his future. Would you advise her/him to study mathematics?

I do not want to answer these questions - it is up to you. But I want to discuss the basic facts, as I see them. First: What means "shaping a century"? To do something, which will influence the life of the next generations! Life has several sides and Miguel de Guzman talks about the "inner life", the normative power and risks of mathematics, Alexandra Bellow about the cultural side and how it is, will be perceived by "intellectuals" - and I want to look at the outer life.

Can mathematics contribute to how people will be living, which tools
they will have and how healthy or even how long they will live? Can
mathematicians make essential contributions to life sciences, to material sciences, to the design of products and production processes, to the processing of information and the management of knowledge? I believe that those, who are interested to shape, are, at the same time, self-confident. The answer of these mathematicians is a clear "yes". But let us look at the situation from the outside, with the eyes of the others. Then, my experience creates some doubts, whether we would get a very positive answer. Of course, the "man on the street" would not count mathematics as one of the most useful sciences (there might be differences between the different parts of Europe - in
France f.e. the situation might be better than in Germany). But even the "movers and shakers" of our society, people in industry, politics are not overwhelmingly positive. My most important experience during the last 5 years, the establishing of a Fraunhofer Institute for Mathematics, may serve as an example. Fraunhofer is a German applied research organisation with (now) 48 institutes and 7000 scientists; the Fraunhofer world is a fantastic high tech world, with outstanding research in almost all modern technologies. Last year it became 50 years old and, at this

occasion, it was internationally evaluated as world wide one of the best applied research organisations. Did Fraunhofer have, or less, did it at least consider to establish a mathematics institute, 5 years ago? No, not really. But there are also good news: Now, after a 5 year test period, the Fraunhofer society has changed her mind, has founded the "Fraunhofer Institute for Industrial Mathematics" at Kaiserslautern - we were able to fulfil the rather tough, economic and scientific conditions. Fraunhofer at the end definitely did welcome us. It is possible to convince the outer world that mathematics is really important. How can we do it? What is mathematics today, what should it be? I am strongly convinced that mathematics is in a phase transition; for quite some time almost exclusively determined by inner-mathematical questions, it begins to open itself for other disciplines. Cooperations with natural and computer scientists, with technologists and economists are growing - and that is exactly what adds new prestige to mathematics. This is my first credo: Only as an interdisciplinary science, mathematics can contribute in shaping the future. This may even be true for other sciences too. Hubert Markl, president of the Max-Planck Society (the "fundamental" brother of the "applied" Fraunhofer) answered the question, whether biology was going to be the leading science in the 21st century: "There is a fast developing fundamental growing together of all scientific disciplines, together with applied mathematics, which as a result will become one science of nature, including vast fields of philosophy, psychology, sociology and medicine. And this will be much more important for the development of science in the next century than a

supposed superiority of biology. This combination of mathematics, physics, chemistry and biology has offered the
opportunity and will be more and more the basis on which biosciences will be able to face those problems that had been too difficult to solve before without interdiscisplinary help; I talk about the investigation of all phenomena of life down to their molecular, causal details." (cited from "Visionen 2000", Brockhaus 1999, translated by H.N.) In this concept of mathematics it is neither the "queen of science" nor its "slave" but an appreciated partner of computer science, natural science, technics, economy and social sciences. And,
as such, mathematics can make significant contributions in shaping the next century; more: It may even have a key role for key- and basic technologies. Everything fine now? I am afraid: not completely. In the public perception there seem to exist two kinds of mathematics: the mathematics made by mathematicians, mainly taught in schools and at universities - and the mathematics done by physicists, engineers, economists ... No doubt: Mathematics is also made outside the community of the professional mathematicians, quite a lot. It is different, less theorems and proofs, more modelling and algorithms. But it is seen as mathematics as well, fortunately I would say in spite of the fact that many of my colleagues are very reluctant in accepting it as such. This kind of "practical mathematics" has a much higher reputation as being useful than the "mathematics of the mathematicians". Georg Christoph Lichtenberg, a German philosopher and a "sharp tongue" stated the same perception as a caricature: "Mathematics is a wonderful science, but the mathematicians are very often not worth a dime." (translation H.N.) It is of course

overdone, but some truth is still in it. In June 2000, I met the director of the famous Indian Institute of Science in Bangalore. He agreed to the idea that practical mathematics has become extremely important and told that he is in the process of creating a Center for Applied Mathematics. A center with physicists, chemists, engineers - whether the department of mathematics, which he considered as quite pure, will play an important role in it, was not so clear. A center for mathematics without input of the (professional) mathematicians: This would be bad for the center and bad for the mathematicians too. And both sides have to approach each other: The director and his center must recognise the value of theorems and proofs - the mathematicians must understand that modelling and computing is good mathematics too! Not only in Bangalore, but everywhere, in Europe too. Once more: Engineers and scientists are all doing "computational X", where X
stands for mechanics, physics, chemistry, biology, geodesy, ..., they all do modelling and scientific computing. They are not convinced that mathematicians are able to improve their work. But they are - and we have to deliver convincing examples, striking arguments (to do this is another lecture, thought for another audience). We have to convince them, but even more important we have to convince our high school students; they seem to have lost their interest in mathematics or physics; if anything they study computer science. This seems to be a European wide problem, maybe with exceptions in Spain, Portugal and Greece. If we are not able to demonstrate the "meaning" and therefore the importance of mathematics - no: of mathematicians - we will loose more and more students, we will loose positions, we will loose chances

for our graduates. No: We are not living in a booming period of university mathematics - in spite of the fact that we are convinced to be able to shape the 21st century. The image of mathematics we create outside our community may attract novelists, movie makers, artists - but not European students. What to do? Already at the beginning of this contribution I pointed to the fact that we have to find and demonstrate our role in an interdisciplinary, comprehensive scientific work. We have to understand ourselves as MINT - professionals,
where MINT is M=mathematics, I=informatics, N=natural sciences,
T=technology, but if somebody prefers the American meaning of the word
mint as "at the top", that is also fine. We have to learn the language of INT and we have to become aware of the problems of the real world, the practical questions posed by industry and management. We have to understand that many of them are mathematical problems too - not only problems for mathematics, but MINT-problems. We have to re-conquer fields of research, which are genuinely mathematical, but which have benn left to others, for example image processing (the work of Yves Meyer, also presented at this conference, is an outstanding example, how rewarding such a process for the solution of practical problems and for theoretical mathematics can be); similar fields are system and control, computational mechanics etc. By "re-conquering" I do not mean that we should consider them as a purely mathematical subject, but as a MINT-activity, in which M plays an important role. Let me give two short examples from our Fraunhofer experience, which may demonstrate the kind of mathematics we are expected to invent. The first one

belongs to material sciences - in his ICM-lecture at Berlin 1999 Avner
Friedman was also pointing to the importance of mathematics in material sciences. I refer to "fatigue life analysis", the aging and damaging of material (as metal or concrete) under irregular loading. Many attempts have been made, many models and theories have been applied, but all are not completely satisfactory. Classical continuum mechanics needs better concepts for higher dimensional hysteresis; stochastic and/or deterministic theories of crack creation and evolution miss a scientific (and mathematical) basis; new stochastic processes must be invented or generalized. But most important: All these very different models must be put under one umbrella, we need a
unifying theoretical frame. To do so, we need to create new mathematics, new algorithms and/or the justification of existing ones. Again: not Mathematicians alone, but together with physicists and engineers. The second example I want to mention is medicine. How many processes in the human body are really "understood" - understanding in the sense of a reliable prediction of the input-output system "human body"? Medicine has just started to collect medical data over long time periods; this means that we have a rich quantitative experience, from which we can learn about the system. Consider for example heart beat time series from long term electrocardiograms; representing these time series by Poincaré diagrams we get rather irregular point clouds, which carry the information about the medical state of the heart. But this information is not yet readable; medicine, looked at it from this
point of view, is in a "precopernikan" state. Mathematics -

what else- has to discover the law enabling us to extract this information. To which field of mathematics, however, does this classification task for point clouds belong to? And, of course, mathematicians alone cannot do it; teams of physicians, computer scientists and mathematicians are needed.

Two examples pointing into a direction, in which I believe the future of mathematics, which is able to shape the 21st century may lay. That does not mean that all mathematicians should leave their traditional research areas and jump on subjects originating from material-, bio- or information sciences. We will still need new pure mathematics supplying us with structures needed for a proper modelling of MINT-problems. We need excellent (but not so much second rate) pure mathematicians, still driven by the inner evolution of mathematics, but at least with an open ear for applied mathematicians, who should act as bridge builders. These have to have knowledge on both sides of
the bridge - they develop or use and adopt theoretical concepts and, at the same time, they know about the "needs of the world". And, moreover, they should be excellent users of the powerful tool they have today: the computer. Several years ago, the mathematical community discussed seriously, whether mathematics should not care at all for the computer or whether computer will make mathematics superfluous. Today we know how ridiculous this discussion was: Computing has risen the importance of mathematics enormously. What
would be our situation today, what would be our chances for shaping the future without computer? There are still mathematicians, who have not yet realized the importance of computing for mathematics or, at least, believe that the

biggest issue is whether a computer based proof is acceptable or not; these people contribute to the above mentioned schism between "useful mathematics" and "mathematics of the mathematicians".

A last word about pure and applied mathematics: Of course they are
different, for example by the origin of the problems. But pure and applied mathematicians need each other, today more than ever - and optimal are those, who are able to do both. Pure and applied mathematics is different, pure and applied mathematicians not necessarily! Shaping the 21st century means to do the research requested by this task, but means to educate young people in a proper way as well. "Proper" education for me is education of mathematicians
as MINT-professionals. And, in order to do so, we first need students at all. As I said already, in many parts of Europe (with some exceptions in the south) the number of MINT-students, especially of Math-students has drastically decreased. This is a phenomenon of the Western world - the rest of the world, Asia, Africa, Latin-America - is full of highly interested, highly motivated and intelligent young people and I can see no reason, why we should not educate these students. Nevertheless, the question remains, why "our" young people
are not much interested - in spite of an outstandingly good job market! Do we, do the schools give the wrong idea about what mathematics is? Do we tell them that mathematics is not only a formal, rigorous science, but that mathematical notions and theories have a "meaning", that mathematics really helps to solve urgent problems of our world? Do we educate mathematicians - and especially mathematics teachers - as interdisciplinary scientists, as

MINT-professionals? I
believe that "interdisciplinary mathematics" may only be learnt by doing - whether we organize it as "modelling seminars", as "labs", as "project work" or as well prepared placements is a matter of task. But that applied mathematicians have to engage themselves in education (school and university) is obvious, the only risk is that they focus too much on their specialities - education of MINT-professionals is education of generalists, since one never knows in advance to which mathematical field a practical problem belongs to.

To come to an end: Yes, mathematics is - in principle - very able to contribute to the shaping of the 21st century. No, we cannot go on as in the past, if we want to achieve it: We have to understand Mathematics as the top of MINT, important but not alone; Mathematics may even be a key technology, if we understand it as part of a "comprehensive science", as an interdisciplinary activity. For that, we have to open our eyes for the outer world and we have to put efforts in an adequate education of the young generation.