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THE POPULARIZATION OF MATHEMATICS

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Unlike other sciences, mathematics, or at least some parts of it, is taught to all schoolchildren; it is this which makes mathematics teaching and mathematics education so important. On the other hand there are few, if any, sciences which arouse such negative reactions or are as badly understood as mathematics. Most people, for example, would not even consider mathematics to be a living science. This study will be concerned with the public image of mathematics and mathematicians. It will seek to identify specific needs and to suggest ways in which mathematics can be more effectively popularized. Some of these needs and ways are not particular to mathematics;they also concern the popularization of any individual science, or of sciences in general. However, the popularization of mathematics has special features; obstacles, constraints and difficulties on the one hand, important possibilities and opportunities on the other. The present situation and record of past achievements differ from country to country and there is a need for international discussion in order to compare experiences, to clarify issues, and to promote further reflections and actions. This study, then, marks an important step forward, for it is intended that there should be a major gathering of those interested (in Leeds, England from 17-22 September, 1989) and that this should be accompanied by a nationally-organised, yet international, "event" comprising a major exhibition, films, videos and lectures.

The Leeds meeting, therefore, has two aspects: a national event and an international study. Each aspect will benefit from the other and the planning of the two will be closely coordinated. The present discussion document is the first contribution to the international study. We hope that, like discussion documents issued in connection with previous ICMI studies, it will stimulate written contributions from all over the world. Such contributions, together with the present document, will form the basis for reports and discussion in Leeds. The resulting *Proceedings* of the meeting will then be published as ICMI Study 5.

1. A GENERAL FRAMEWORK: NEEDS AND METHODS FOR THE POPULARIZATION OF SCIENCE

Let us begin by making a few simple observations.

Advances in science and the day-to-day lives of humans are indirectly but, nevertheless, intimately connected. Strategical choices by states relating to economic, military and environmental matters, are fashioned by changes in technology and give rise to new technological challenges. Chains of relationships are then built up affecting all types of employment, the environment, public health, communications, home and family life, ... An informed citizen, whatever his or her occupation, should have some understanding of the crucial points on which these strategical choices are taken, some knowledge of the scientific advances appertaining to the technologies under consideration. Such a general scientific understanding is a democratic and economic need in every modern society and the provision of it may well be one of the decisive social challenges in the future.

However, there is now an increasing divergence between the advancement of science and the general understanding of the vast majority of human beings. Though science is universal and should help promote unity amongst people, we see that scientific research and scientific education may actually be organised in ways which increase inequalities and frustrations. Although scientific concepts are involved in every modern device used in everyday life, too many people are unable to grasp scientific ideas, do not know what a scientific way of thinking is, and, as a result, are too frequently pushed into irrational modes of thought. Even those who were well educated and equipped with some scientific knowledge all too often lack the time and incentive to enlarge their scientific understanding and to keep abreast of modern developments.

This, then, is the situation to which those involved with the popularization of science must respond. On the one hand there is an exponential increase of scientific knowledge produced by, and circulating amongst, small groups of specialists. On the other hand, there is a general, social need for a popular understanding of scientific discoveries, scientific achievements, scientific ideas, and scientific modes of thought. Any efforts to bridge that gap are part of popularization in its widest sense. In a more restricted sense, and that which this study will consider, the popularization of science involves all efforts made, or which might be made, to bridge the gap between scientific advances and public knowledge and information, apart from those which take place within school systems and in higher education.

The process of popularization involves three factors: the topics to be considered, the sections of the public it is wished to interest in the topics, and the media to be used in the processes of communication. To help in the making of consequent choices there will be a clear need to identify specific aims and criteria for decision-making.

No topic should be excluded *a priori.* Whenever there is a real advance in science it has to be known outside the small circle of specialists which participated in that advance — or it risks becoming lost. Any effort to make it known, to explain its meaning to a wider audience, is part of the process of popularization which can take place at a number of levels. At the highest level, the dissemination of advanced topics (through, say, expository papers) is an extreme, but an essential, stage in the general process. Yet there are many other topics of interest apart from contemporary research: for example, the history of a subject, its applications (particularly any of a novel character) and an understanding of the type of people involved in that science and of their motivation.

Similarly, no section of the public should be excluded. Children of all ages, workers, citizens, all types of professionals, even other scientists. All motivations have to be considered: professional interest, curiosity, general knowledge, ... , but also prejudices and fears.

All channels, too, must be exploited: books, newspapers, periodicals, films, exhibits, TV and radio programmes, software, ... Education and continuing education will play a decisive rôle complementary to that of popularization. Games and competitions will have a part to play — particularly in mathematics. Whatever the medium, popularization will be analogous to translation, and its quality will depend upon the skills and experience of the translator. Some of these are professionals: scientific writers and journalists. These may well have a catalytic rôle to play in involving scientists, teachers and other professionals in the general process of popularization.

2. Special features of the popularization of mathematics

The popularization of mathematics gives rise to certain special problems. First, many people's relationship to mathematics is governed by what happened to them in school. The affective consequences were often considerable: love, interest, dislike, hatred and, all too often, fear. It has to do with success in school mathematics and with the common belief that mathematics needs a special kind of mind and attracts only those of a particular disposition.

Mathematicians may reinforce this belief, either by refusing to participate in the subject's popularization, or by the way in which they behave or explain things to laymen.

"Mark all Mathematical heads which be wholly and only bent on these sciences, how solitary they be themselves, how unfit to live with others, how unapt to serve the world".

This view of mathematicians, expressed by Roger Ascham, 16th century educator and tutor to Queen Elizabeth I of England, is one which is echoed in many later writings. Blaise Pascal, who was himself intimately concerned with mathematics, used to contrast "esprit de géométrie" (a mathematical mind) with "esprit de finesse" (an accurate mind). The latter was an attribute of "honnêtes gens" (nobility and the high bourgeoisie), whereas the former was poorly regarded. This contrast has been a favourite theme for dissertations in French high schools, and has contributed to the view of mathematicians as strange characters, divorced from the real world.

Mathematicians may well reinforce this view when they speak or write about themselves and the mathematical world. As H. E. Robbins, himself a noted popularizer, puts it in his review of Ulam's *Adventures of a Mathematician*: if mathematicians appear as "thinking machines on the make, without discernible relation to parents, spouses or children, and oblivious to the human concerns of our times, ... if mathematical intelligence is strongly associated with emotional deprivation and social alienation, then ... we ... are in for trouble".

Let us raise a few questions for discussion. What is the popular view of a mathematician? To what extent does that view influence both the wish to study mathematics, or, should the possibility arise, to support mathematicians in their work? To what extent do books or films about mathematics or mathematicians reinforce unfortunate beliefs?

Given the importance of the affective relation of individuals with mathematics, can we agree that one purpose of popularization must be to create a favourable mental association with mathematics whenever and wherever it might arise?

A second special feature of mathematics which hinders popularization is the kind of topics on which mathematicians work.

Even the most abstract parts of physics or biology have a direct connection with some practically important and familiar subject, such as energy, space, the environment, or health. Topology in 3- or 4- dimensional spaces, finite groups, or properties of $\zeta(s)$ in the critical strip cannot be connected as easily with important, real life problems. (And attempts to link them with unimportant real-life situations may well prove counter-productive.) As L. A. Steen has pointed out ("Mathematics; our invisible culture") it may well be that the research frontier of mathematics is yet another order of magnitude more difficult to communicate than other frontiers of science, and that in many instances not even a professional scientist will attempt to comprehend a new mathematical direction.

This apparently contradicts our previous ruling that no topic should automatically be excluded from popularization. It raises the question: "In the present state of mathematics and mathematical research, are there topics which can be explained only to an audience of mathematicians?"

Even at the level of an expository article for mathematicians there is another difficulty. Science is never a mere accumulation of results, but this is even more the case in mathematics than for any other science. When a theorem is produced, the most important result may be the lemmas. When a problem is solved, then it immediately loses its interest — the new focus of interest are the methods used in the solution. Theorems and problems have, in the main, but a limited time in the spotlight. It is the lemmas and methods which provide the matter for new theories, new concepts, new definitions.

How is it possible convincingly to present the real dynamics of mathematics as a living science?

The public image of mathematics and mathematicians and the esoteric character of advanced topics make its popularization extremely difficult. Yet other features of mathematics may ease our task.

(a) *The rôle of problems*

Problem-solving is a part of school mathematics, as well as a part of the activity of professional mathematicians. In no school activity can the activity of the professional researcher be more closely mirrored. "How to solve it" is a natural and powerful introduction to results and methods. Popularization, then, is not concerned solely with transmitting information, but also includes the involvement of the public in mathematical activities.

(b) *Historical and cultural links*

No other science can boast such a history nor can exhibit so many cultural links. For example, ICMI Study 1 *(The influence of computers and informatics on mathematics and its teaching)* showed how these historical links can be reinforced by the use of computers, for under their influence many parts of mathematics have come to life again after a long period of lying dormant. To trace the history of a topic may be an easy and useful approach to popularization at every level. Alternatively, to see how the same demands in different societies have led to similar, even if superficially different, mathematical ideas can show the extent to which mathematics is culturally based.

(c) *New applications*

In the past twenty years mathematics has been recognised as a useful, indeed essential, tool in many disciplines and technologies. ICMI Study 3 *(Mathematics as a service subject)* considers the implications of this within higher education. Yet the implications are equally great for continuing education and for popularization. The interest of the public in the applications of mathematics — in their contribution to societal well-being — can well stimulate an interest in the mathematics involved.

What other "positive" features are there to be considered?

3. The methods of popularization

The methods used must depend on the kind of public on which particular efforts are being targetted. We want to set the switches so that people will look forward to mathematics, and to the use of mathematics, in a great variety of circumstances. If one is young, this means that one looks forward to mathematics in one's own education; if older, to the use of mathematics in everyday life, in one's job and in civic responsibilities, and to the part mathematics will play in the education of one's children or grandchildren.

Popular lectures, television, museums, travelling exhibitions, films, plays, ... may all be used in order to create this favourable mental association with mathematics. We hope that one outcome of this study will be the collection of a set of good examples coming from different parts of the world. We suggest that there should be a careful study of specific displays, films or books about mathematics or mathematicians from different points of view: their aims and objectives, their quality, the positive impact they have made ("favourable mental association"), their negative impact ("mark all Mathematical heads ...") and, in general, the reactions of the target audience.

Many people, through their careers and professions, are provided with important motivation for renewing contact with some areas of mathematics. Popularization may provide a "second chance" for those whose previous educational experiences of mathematics have not been successful. Many "popular books" on mathematics can serve this end. Popularization may satisfy a specific need in relation to new technologies (robotics, computer graphics, computer assisted design, ...), statistical methods in social sciences, agriculture, biology, ... , operations research in management, ...; part of it may be included in continuing education, in self- educational software, or in the general scientific and technical information contained in professional journals. How is this kind of popularization best organised? What are the potential traps to be avoided? How can one estimate the needs of the users and their reactions towards the books, etc., which they use?

Scientists are a particular case, as is the community of professional mathematicians and mathematics teachers at all levels of education. Are we satisfied with the expository papers and books on new trends in mathematics? If not, what can we suggest?

Involving others in mathematical activities is a very special way of popularization to some extent unconnected with trends in modern mathematics, for much use can still be made of classical concepts and puzzles. The wolf, goat and cabbage problem has entertained countless people for over a thousand years and will no doubt continue to do so. Mathematical columns in newspapers, mathematical puzzles such as Rubik's cube and many games, for example mweso or wari in Africa, have excited the interest and curiosity of millions. How can we make best use of these opportunities for popularization? Can we analyse the relation between "savoir faire" in puzzles and games, and mathematical modes of thought? If we use such methods of popularization, how do we prevent mathematics from being associated with the solution of inconsequential problems?

Recently mathematical competitions have developed and attracted public attention in many countries. What is the impact on society of such competitions as the very selective International Mathematical Olympiads and of competitions which are open to a much wider section of children, such as the Australian National Competition?

The links with history and culture are not always used as they might be. There are vast mines to explore. The history of mathematics is beginning to be treated as part of general human history and references now appear in books or collections. Greater emphasis is being placed on the study of mathematics in different societies and cultures. How can this new knowledge be exploited? Are there good examples of popularization which can be described and commented upon? In what ways can the multicultural aspects of mathematics be used as a stimulus for its study? As we have written above, new technologies provided new stimulation and new tools. Computer graphics have enabled new and advanced mathematics to be introduced to vast numbers of people: think of the interest aroused because of the great beauty of the graphics associated with Julia and Mandelbrot sets. A new range of mathematical activities can also be introduced through the computer. How can the micro best be used in the popularization of mathematics? What software exists for this purpose? How effectively does it involve the user in mathematics, rather than, say, in art?

Not all of these questions will be appropriate for those in developing countries. Yet there is a rich amount of mathematical experience in each ethnic group, often described as ethnomathematics. To what extent is this experience related to the public image of mathemtics and how can it be employed in popularizing the subject?

Methods are nothing without practitioners. This study provides an opportunity to gather personal experiences and views, to appreciate the specific rôle of a few gifted personalities (adept popularizers or popular figures from the mathematical world), and to stimulate the participation of all mathematicians and mathematics teachers in the process of popularization. In particular, the responsibility of professional mathematicians for popularization must be more carefully spelled out. What personal part should each play? How can mathematics teachers be best involved in the process?

How can writers and dramatists be encouraged to develop mathematical themes? How can reading and publishing be stimulated? How can we build on the very best examples of popularization which can be seen, read, heard and participated in today?

CALL FOR PAPERS

We hope that readers of this discussion document will respond to it by writing papers on specific themes or questions. These will be welcomed both from those who cannot participate in the closed international seminar and from those who would like an invitation (the number of which will be limited) to do so. Papers should be submitted *no later than* 30 April, 1989. Copies should be sent to

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Remember that, by themselves, descriptions of attempts at popularization will have little value. There is a need to put the attempt within a particular context: to describe the target audience, the choices made (relating both to material and medium), and to provide some type of evaluation — however subjective — what works, what are the traps to avoid.

Those wishing to submit films, videos, ... for possible exhibition or to nominate books which might be included in a display should write to G. T. Wain, School of Education, The University, Leeds LS2 9JT. Please send a full description including technical details (length, subject matter, intended audience, ...).

There will be financial assistance available to bring some participants from developing countries to Leeds. Other participants, however, will, in general, be expected to pay their own travel and subsistence costs. There will be no conference fee for the international seminar.

Previous ICMI Studies

The influence of computers and informatics on mathematics and its teaching, Cambridge University Press, 1986.

School Mathematics in the 1990s, Cambridge University Press, 1987.

Mathematics as a service subject, Cambridge University Press, 1988. (See also, *Selected papers on the teaching of mathematics as a service subject,* Springer-Verlag, 1988.)

In preparation: *Mathematics Education and Cognition.*

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