OPETUSMINISTERIÖ

AN EVALUATION REPORT
ON THE LUMA PROGRAMME
PREPARED FOR THE MINISTRY OF EDUCATION

By

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(Internationell utvärderingsrapport av LUMA-programmet)

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Tiivistelmä

Opetusministeriön LUMA-ohjelman kansainvälisen arviointiryhmän tehtävänä oli arvioida LUMA-ohjelman toteutumista kansainvälisestä näkökulmasta sekä antaa suosituksia matematiikan ja luonnontieteiden osaamisen parantamiseksi tulevaisuudessa.

Ryhmän antamat suositukset on koottu raportin alkuun. Niitä selitetään ja perustellaan raportin tekstiosassa.

Luvussa yksi annetaan yleiskuva LUMA-ohjelmasta ja arviointiryhmän työstä. Luvuissa 2 – 8 kuvataan kuntien, koulujen, korkeakoulujen ja elinkeinoelämän roolia LUMA-ohjelmassa. Kahdessa näistä kappaleista käsitellään oppilaiden ja opiskelijoiden arviointia sekä LUMAan liittyvää tutkimusta ja arviointia. Luvussa kahdeksan arvioidaan LUMA-ohjelmaa prosessina.

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Sammandrag

Uppdraget för den internationella utvärderingsgruppen gällande undervisningsministeriets LUMA-program var att bedöma programmets förverkligande ur internationell synvinkel och att ge rekommendationer för att förbättra finländarnas kunskaper i matematik och naturvetenskaper i framtiden.

Gruppens rekommendationer har samlats i början av rapporten. De förklaras och motiveras i rapportens textdel.

I kapitel 1 ger man en översikt av LUMA-programmet och utvärderingsgruppens arbete. I kapitlen 2 – 8 beskrivs rollen hos kommunerna, skolorna, högskolorna och näringslivet i LUMA-programmet. I två av dessa kapitel diskuteras den bedömning av elever och studerande samt den forskning och utvärdering som anknyts till LUMA-programmet. I kapitel åtta bedömer man LUMA-programmet som process.

Nyckelord
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Abstract

The task of the international evaluation group of the Ministry of Education's LUMA programme was to evaluate the design, implementation and results of the programme from an international perspective, and to recommend future measures for improving mathematical and scientific know-how in Finland.

The recommendations for the future are summarised at the beginning of the report. They are explained and justified at appropriate points in the chapter texts.

In chapter one an overview of the LUMA programme and of the work of the evaluation group is given. In chapters 2 to 8 one describes the role in the LUMA programme of municipalities, schools, universities and polytechnics, and industry. In two of these chapters one also discusses examinations and assessment, and research and evaluation with respect to LUMA. In Chapter 8 one assesses the process of LUMA and discusses positive and negative aspects of the programme.

Key words
Mathematical know-how, scientific know-how, evaluation

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OUR RECOMMENDATIONS

Each of these recommendations is supported by more detailed arguments in the text that follows. Some are linked to arguments in more than one chapter. The numbers in brackets refer to these links by reference to numbered 'proposals' e.g. 3.1 refers to the first proposal in chapter 3.

A. A future for LUMA

We recommend that a new initiative for the dissemination of the practices and other valuable outcomes of the LUMA programme be formulated and implemented as soon as possible. The programme has produced a substantial investment, and has yielded both skilled and committed teachers and potentially valuable ideas about the oganisation and process of reform.

Without a *follow-up programme* and in the absence of any persons having particular responsibility and dedicated time to maintain and expand the activities this investment will be wasted, for it is likely that the improvements established so far will not spread, and may indeed slowly decline even in current LUMA schools (8.1).

B. The future role of co-ordinators

B1. The key people required for any future dissemination will be the *municipal coordinators*. This points to the need for funding a team of coordinators, supported by a national co-ordinator, whose task will be to advertise more effectively the positive outcomes of LUMA and to facilitate non-participants (in LUMA) to adopt good practices (2.2, 3.4).

B2. Research effort should be dedicated to fully interpreting the contribution made by municipalities to promoting the programme, so that guidelines for effective procedures can be identified for the future (2.1).

B3. Some experienced teachers should also be given part-time release to support dissemination work as *local co-ordinators*. The tasks of these teachers would be to sustain the existing work in LUMA schools, and to help disseminate and to expand the LUMA activities to schools and municipalities not involved so far. Such support could help to reap the potential rewards of the LUMA work, both directly, in the work that these co-ordinators could do, and indirectly in making clear to those who have worked hard so far in LUMA that their efforts have been recognised as worthy of further support so that they would be encouraged to continue (3.1, 3.4).

C. Professional development of teachers

C1. For *initial training*, Universities and Polytechnics responsible for the relevant

programmes in mathematics and the sciences should be required to undertake a thorough review of them. Such review should pay particular attention to closer collaboration between the education and the mathematics and science subject departments, and to co-ordination so that, for example, subject studies are relevant to the subject needs of future teachers. Courses must achieve a balance between studies of each subject, studies of the pedagogy of the subject, such studies as those in psychology of learning, and practice work in teaching in schools. There should be more involvement of practising classroom teachers in these programmes. Master theses by future teachers should usually focus on an educational theme (5.8, 5.10).

C2. There is also need for the continuation of an intensive *in-service programme* and for the adaptation of courses so that they provide the ingredients necessary to encourage change in classroom practice. In particular LUMA teachers who have developed good practice should be drawn into in-service courses, designed as part of a programme aimed to develop and disseminate further the good practices in pedagogy developed already in the best LUMA schools, and also to strengthen the mathematics and science knowledge of class teachers. The teachers, and the university departments both in science and mathematics and in education, who have contributed so far to the LUMA achievements should collaborate in the design and conduct of this training, giving priority to methods and content which would promote and support change in the classroom work of teachers. Further development of the Open University approach would make a valuable contribution here (3.5, 5.6, 5.7, 5.9).

D. An Open University

National collaboration between the open universities and co-ordination of their programmes should be initiated as soon as possible. This should aim to produce the pooling of expertise and enhancement of quality which is essential if the courses are to reach the best international standards in promoting learning. A quality resource in this area would be an important asset, both for the further education of adults, and in particular for in-service training of teachers (5.5).

E. Evolution of the mathematics and science curricula

E1. The *curriculum* for mathematics and the sciences should be reviewed in the light of the LUMA findings. Teachers in successful LUMA schools and personnel from the industries who have been supporting school work in mathematics and the sciences should be consulted. An important principle in such consultation would be to identify how the curriculum could be changed in such a way that the school work would be more attractive to students and be seen by them to be more relevant to their interests and concerns than it is at present (3.2, 7.1).

E2. In revision of the curriculum, particular attention should be paid to the *balance between mathematics, the sciences and technology*. For comprehensive education,

upper secondary and vocational education, the expertise of industrial liaison personnel should be drawn in. Such reforms should support the broadening of the science curriculum to reflect the relevance of science to the life of citizens, to modern technology and to the uses of science and mathematics in business and industry (3.6, 5.4). In addition, the concept of a 4-year term (matriculation plus vocational certificate) for an integrated science with technology programme should be fostered, because it has the potential to produce well-rounded and informed students for science and technology study in higher education (3.3).

E3. There is a need to clarify the position of *practical work* in upper secondary science, primarily from the point of view of curriculum purpose, and in the light of that in relation to appropriate assessment, teacher training, capital needs, maintenance and technical assistance (2.3, 3.7, 4.3).

E4. Measures should be taken to try to understand the reasons for the decline of the level of *mathematical skills and knowledge of students* entering tertiary education and to devise strategies to address this problem (5.1).

E5. For all of the changes recommended above there is a matching need for re-appraisal of the way in which curriculum *aims are supported in assessment and testing* systems (4.2).

F. Examinations and assessments

F1. The *leaving examinations and assessments*, notably the matriculation examination at the end of upper secondary, and the certificate in vocational schools, should be reconstructed to give a full picture of a students' attainments so that it is no longer necessary for the Universities and Polytechnics to set their own entrance examinations. To this end, the Universities and Polytechnics should be involved in the formulation of any revision. The effects of any revision on student motivation and on the curriculum should be borne in mind (4.1, 4.2, 4.3, 5.2)

F2. Pilot studies should also be commenced to explore ways of ensuring that *assessments by teachers* are comparable across schools so that they can contribute directly to the matriculation result : this will be particularly important if assessments of pupils' achievements in practical sciences are to contribute, as they should, to the matriculation results in the future. A similar need arises in relation to the comparability across schools of teachers' assessments at the end of basic schooling (4.2).

G. Research and evaluation

G1. There are three *specific research studies* which would be useful in completing the evaluation of LUMA and in informing future developments:

The **first** of these is a programme of studies to explore the factors which affect

the attitudes and motivation of school students towards mathematics and science. Such a programme should start with systematic review of the existing literature, which would point to research that might be needed to identify the issues. The overall aim would be to provide a basis for future efforts to make further progress with the main objectives of the LUMA programme (3.8, 6.1, 6.3).

The **second**, related to the first, is a study of the effects on students' attitudes and study choices of the present structure of the general studies paper in the matriculation examination, and of the likely effect of changes in this examination (4.2).

The **third** is research aimed at documenting and interpreting the contribution made by municipalities to promoting the LUMA programme, so that guidelines for effective procedures can be identified for the future (2.1).

G2. The research capacity in areas relevant to the pedagogy of mathematics and the sciences needs to be strengthened in order that future work to improve both current curricula, assessments, classroom practice, initial training and professional development of teachers can be informed by deeper understanding of the nature of the problems to be tackled and of the needs to be met. Wherever possible, teachers should be involved as collaborators in such research. The existing programme to improve the training of doctoral students should be continued, but should be located in only two or three centres with strong co-ordination between them (5.9, 6.4)

G3. There should be an audit of current research programmes in education, in universities and in other institutions, in order to evaluate their likely contribution to policy and practice in the future. A proportion of any future funding available for research should give preference to studies which are designed to deliver such contributions, and increased co-operation between teachers from subject and educational departments should be promoted. (5.10, 6.2).

H. The contribution of business and industry

We recognize the *contribution by business and industry* to education and the LUMA programme, and recommend that they become more involved in the educational process. More attention should be paid to the qualities they will value in future employees, and in the future, in order to achieve this aim, they should be consulted about curriculum reforms (7.1).

I. Funding needs

General comment on the funding of the education system is outside our remit. However, we have encountered two particular problems related to inequities in the distribution of funding to which we feel we ought to draw attention.

I1. The provision of practical *science apparatus* in schools seems very uneven. All upper secondary schools should benefit from a science budget from the NBE. Such budget would be used for the purchase of the items of equipment that would bring their stocks up to a level that would be "fair" according to the criteria used for the survey of premises and equipment undertaken by the NBE in autumn 1996 (2.3).

I2. In order to *support fairly* those university and polytechnic departments, notably in *mathematics*, who have a heavy load of service teaching for students from other departments, the funding of the departments should be re-aligned so that the numbers of students and credit points actually taught is taken into consideration (5.3).

CHAPTER 1

OVERVIEW

The LUMA programme

The national joint programme LUMA started in 1996. It was revised in 1999 and the final report of the LUMA programme will be presented this year. The general objective of the LUMA programme has been to raise the level of mathematical and scientific knowledge and expertise in Finland to an international level. The reason for the programme is the growing and all-pervading importance of mathematics, natural sciences and technology in societies, and hence the need both for experts well qualified in these areas and for a sound understanding by all citizens of the issues that they raise.

The objectives of the LUMA programme are both qualitative and quantitative. Quantitative goals have been to increase the combined intake in universities and polytechnics in the natural sciences and technology; to increase the number of candidates who take advanced mathematics, physics and chemistry in the matriculation examination; to improve gender equality; and to increase the number of mathematics and science teachers in order to meet the needs for education at all levels and ages. Qualitative goals have been that pupils and students will obtain comprehensive knowledge and skills in mathematics and natural sciences; that vocational students will attain mathematical and scientific knowledge and skills needed in different fields and occupations and for further study; and that citizens will have the opportunity to acquire the mathematical and scientific knowledge they need.

The implementation of the LUMA programme is very diverse. The programme consisted of ten major projects and many sub-projects. These projects and the objectives of the LUMA programme are discussed in detail in the final LUMA report. The content of the ten major projects may be summarized as follows:

P1. Formation of a network for communication, development and dissemination of ideas between municipalities, schools and educational establishments.
P2. Assessment, research and researcher training related to the LUMA programme.
P3. Increased weight of mathematics and the natural sciences.
P4. Quality assessments as a natural part of the learning process.
P5. Equality-promoting projects.
P6. Special supportive measures. For instance, measures and resources are to be directed, on the one hand, at the most gifted pupils and, on the other, at those faring the least well.
P7. Teacher training reform projects.
P8. Projects for lifelong learning - from pre-school to adult education.
P9. The role of municipalities, business and industry, and research institutes.
P10. Cooperation between universities, polytechnics, upper secondary schools, and vocational institutions.

The work of the evaluation group

The evaluation group consisted of Paul Black (chairman), Aine Allen, and Hans Wallin. We were asked to evaluate the design, implementation and results of the LUMA programme from an international perspective, and to recommend future measures for improving mathematical and scientific know-how in Finland. Our evidence to achieve this has been:

A draft of the final LUMA report and its appendices: "The mathematical and scientific know-how of the Finns in 2002, Final Report of Joint National Action, LUMA Support Group", below referred to as the Report. Evaluation visits during one week to different institutions and organizations (see the Appendix "A record of the visits and consultations of the evaluation team during their week in Finland from 30th September to 4th October " for details). Documentation collected during our evaluation visits.

Our evaluation visits covered many different institutions and we met a wide range of people. We visited a pre-school, primary schools, lower and upper secondary schools, a vocational school, a school for disabled children, a teacher training school, a polytechnic, and university departments of mathematics, physics, chemistry, biology, and teacher education. We also met educational officers and advisers from municipalities, industry, the National Board of Education, and the Ministry of Education. Finally, we met the LUMA Support Group, staff from an institute of educational research, a representative from the Academy of Finland, and officers representing the teachers´ organizations MAOL and BMOL, and the Science Centre Heureka.

The range of the institutions we covered and of people we met was very broad and complete enough to give a good picture of the educational system in Finland and the LUMA programme. We visited both LUMA schools, i.e. schools which had joined the LUMA programme, and non-LUMA schools. We were impressed by the openness and the hospitallity of the people we met, and by the strong engagement of many of them.

During our visit in Finland great help was given to us by the Ministry of Education and the officers of the National Board of Education, in particular by Antero Hietamäki. We are very grateful for this assistance which helped to make our work both productive and comfortable.

Our general view of the LUMA programme

Our overall view is that the LUMA programme has been successful in many respects. We have heard many teachers saying that LUMA has had a decisive influence on their work as teachers. It has helped them to get started with new ideas and projects and to initiate co-operation between teachers and between different subjects, schools, universities and polytechnics, and municipalities. The NBE's LUMA staff made frequent visits to various LUMA events and schools and we understand that this support from the centre was much appreciated by many LUMA teachers. One important ingredient in the whole process has been the LUMA network and its co-ordinators, and the dissemination of new ideas through this network. In addition,

individual teachers and municipalities have played important roles and the LUMA spirit has helped to promote co-operation and to spread good educational ideas through in-service training of teachers and by other contacts.

We have, however, also heard many teachers saying that LUMA has not meant anything to them or to their schools. In many cases a heavy teaching load and lack of time seem to have been initial obstacles to taking interest in LUMA. It is not clear how successful the dissemination of LUMA ideas will be in the future unless special measures are taken. One negative side of the programme which we have observed is that the research base for LUMA is weak. We also think that the matriculation process in its present form has weaknesses which make it difficult to secure some LUMA objectives and to evaluate achievement of them

We do not recommend a continuation of the programme itself but list several recommendations for the future in this report.

The structure of this report

This report is our evaluation report of the LUMA programme.

Our recommendations for the future are summarised at the beginning of this report. They are explained and justified at appropriate points in the chapter texts.

In chapters 2 to 8 we describe the role in the LUMA programme of municipalities, schools, universities and polytechnics, and industry. In two of these chapters we also discuss examinations and assessment, and research and evaluation with respect to LUMA. In Chapter 8 we assess the process of LUMA and discuss positive and negative aspects of the programme.

CHAPTER 2

THE MUNICIPALITIES

The municipalities were a central agency for effecting some of the major changes anticipated for the LUMA project. They were instrumental in the selection and support of the actual projects that would be undertaken in the real educational situations in their remit, i.e. the schools, the vocational institutions and the polytechnics. Many were prepared to undertake a high level of responsibility for their involvement; they were accepting charge of all local projects and committing themselves to communicate with other municipalities for the spread of their discoveries/knowledge.

Pilot Municipalities

The Report indicates that the municipalities were powerful agencies for change. It is understandable that a forward-looking municipality would itself perceive the strategic advantage of participating in the programme. LUMA provided an opportunity for innovation and reform at a local level. Moreover, each municipality had a high level of freedom to design its own LUMA involvement to suit its own particular situation. In retrospect, the careful selection of the 26 pioneering municipalities provided a good pilot test for the objective of networking. The fact that as many as 78 municipalities volunteered to join LUMA in 1999 is seen by us as a testament to good work done by the pioneers and to good information flow about their work.

The Success of Networks

The range and depth of activities initiated and supported by the various municipalities is evident to the evaluators. Effective education development networks were generated and operated by the municipalities. It is clear from the Report that these networks helped to promote curriculum support, teacher collaboration across subjects and schools, school links with polytechnics and universities, in-service training for teachers, and industrial and business partnerships with education institutions. A visit to a full range of educational institutions in a typical municipality made clear to us the concrete nature of the activities that were facilitated by a municipality. The success of the LUMA programme in a local municipality or in a regional network was critically dependent on the success of this networking activity.

However, it is obvious that the success of the networking activity was dependent to a large degree on the good-will and commitment of the key stakeholders involved. Cooperation and communication within networks required time and commitment beyond regular duty on the part of people involved, particularly the teachers. The role of each municipality was to encourage and support specific initiatives, but the schools were left with a high level of autonomy. The teaching development networks flourished in some municipalities and floundered in some others. We interpret this as evidence of the voluntarism that was necessary for success. Positive outcomes depended on a

willingness of individuals to embrace the philosophy of self-managed change. In municipalities where such a strong response was forthcoming from a critical mass of stakeholders, the result was positive. But in municipalities where such strong response was absent, there was too much left to chance. In such situations it is difficult to assess whether schools lost the opportunity to benefit from LUMA despite a disposition to participate, or whether there was inertia on the part of schools to cooperate with the municipality in developing LUMA activities. Out of a total of 78 municipalities officially involved, 56 filed reports to the LUMA Support Group in February 2002. This response rate could be taken as a measure of the level of participation by municipalities. It might be argued that if all these municipalities participated by virtue of volunteering themselves, the expectation would be for a 100% response.

In appears that, despite the framework contract drawn up between each municipality and the NBE, demands made on the municipalities for active participation were not strenuous. In retrospect it seems to us that to allow participants in the project but not demand certain minimum outcomes this was too loose a contract. A more satisfactory assessment of the effectiveness of municipalities in their LUMA role would have been achieved if a template had been provided to them for submitting their reports. The achievements of the municipalities in the different objective areas could then be more clearly interpreted.

> **PROPOSAL 2.1.** Research effort should be dedicated to fully interpreting the contribution made by municipalities to promoting the programme, so that guidelines for effective procedures can be identified for the future (Recommendations B2, G1).

The Role of the Coordinators

The effectiveness of the coordinators, as the executive arm of each of the municipalities in the LUMA programme, was crucial for the advance of the programme. Many very important issues such as the development of clusters, communication with other municipalities, and the spread of good practice, were the responsibility of the coordinator.

We were not able to assess the extent to which co-ordinators, whom we believe were mainly practising teachers, were given time for their LUMA work by release from their normal duties. In some cases the post was full-time but in other cases there was just a reduction in teaching obligations. It would have been useful to have a clearer understanding of the job descriptions for the coordinators and the degree to which this work was accommodated by their municipalities. This would help for the future in identifying critical factors for the success of the work and the capacity of the coordinators to deal with all their duties.

The work envisaged for the municipal coordinators has not yet been completed. There has been little dissemination of LUMA practices and findings to other schools and municipalities. We argue that there is a responsibility to complete this work of dissemination. Valuable outcomes have been identified that should be extended to schools and other educational institutions in all regions of the country. Also, the willing

and committed teachers, coordinators and others people, who dedicated themselves to the project, should be allowed to benefit from information on successful innovations that have taken place elsewhere.

> **PROPOSAL 2.2.** It is necessary, even although the LUMA programme itself does not continue in its present form, that the work of dissemination should be completed. Since the key people required for this dissemination are the municipal coordinators, this points to the need for funding a team of coordinators whose task will be to advertise more effectively the positive outcomes of LUMA and to facilitate non-participants (in LUMA) to adopt good practices (Recommendation B1).

Funding by the Municipalities

Municipalities were responsible for providing a measure of financial support for the LUMA activities in their locality. The Report indicates that there were some large capital investments but we have not seen a breakdown of the way funds were allocated between the different LUMA activities. The different financial needs of schools in different regions were apparent to the evaluators on our visit and we suspect that in some cases the funds available were not adequate to enable the poorer schools to participate fully. The Report documents that some schools did not receive the budget allocation for equipment for upper secondary science, and also that in some instances teachers were obliged make personal contributions to some of the costs incurred for in-service work. The arbitrary nature of the funding and the varying degrees to which the municipalities provided financial support, is judged by us to be a weakness, and we have already referred to this issue in our section above on "The Success of Networks". It is possible that the level of funding channeled to the municipalities for their participation in LUMA was not high enough to motivate them to be more proactive in supporting the activities in their region.

> **PROPOSAL 2.3.** This points to the need for all upper secondary schools to benefit from a science budget from the NBE. Such budget would be used for the purchase of the items of equipment that would bring their stocks up to a level that would be "fair" according to the criteria used for the survey of premises and equipment undertaken by the NBE in autumn 1996 (Recommendations E3, I1).

CHAPTER 3

THE SCHOOLS AND THEIR TEACHERS

Influence of Schools on the Community

The inclusion of all levels and types of schools in the programme was conducive to the rooting of the programme in local communities. The involvement of all ages of children and young people (from pre-primary to upper secondary and inclusive of the vocational sector) in the activities of LUMA served the purpose of heightening awareness of education in mathematics and the natural sciences amongst the community at large. It would have been useful to assess the impact of LUMA on the adult population. This could be measured by the uptake of science education by adults. The desegregation of the data on the increase in Open University students, to reveal adult learning numbers, would provide this information.

It appears that the opportunity to fully exploit the cross-school and cross-community ethos of the project was missed; a communication plan proposed by the LUMA Support Group was only partially implemented. Such a plan, on a municipal level, could have provided impetus to the cooperation of clusters, alerted non-LUMA schools to the programme and contributed overall to the full penetration of the mission of LUMA into the public awareness.

Continuum of Science Learning in Schools

The view of science and mathematics education as a continuum, starting at pre-primary, is a basic feature of the new curriculum which is now due for implementation. LUMA has served to pilot this approach and has demonstrated its merit. The Report provides adequate evidence of a concerted effort to build up good practices for upgrading knowledge and skills in mathematics and natural sciences across all levels. In our visits to representative schools of all types and levels (pre-primary, primary, special education, lower and upper secondary and vocational institutions) we saw concrete examples of the adoption of the LUMA ethos for innovation in teaching and learning. One municipality initiated the use of the term "LUMA tube" to highlight the continuum in science teaching and learning: this seems to us to be a positive concept that should inform strategies for curriculum development in the future.

Important Role of Individual Teachers

It is very clear to the evaluators that the success of LUMA has to be attributed in a large part to teacher-lead innovation. The motivation and initiative of individual teachers was a necessary ingredient for any progress. We note and acknowledge that a time allowance was granted to some teachers to enable them to commit to involvement in teaching and learning innovation. However, from our interviews, it became apparent that in many instances, teachers gave of their own time inside school and outside school, thereby making a commitment over and above their normal duties. It is

inevitable that this extra commitment was in some cases felt as a burden to teachers. This was rewarded in many instances by the discovery of a new approach to teaching and learning – an important qualitative outcome that cannot be measured. As stated by some of those interviewed by us, LUMA "is in the heads of the teachers". We interpret the many initiatives described in the Report and reported to us in person, as testimony to a value-added teaching of mathematics and science. Unfortunately, even although teachers in Finland are not as administratively burdened as, for example, in the U.K., the relative increase in time commitment needed to sustain new approaches to learning is taking its toll, and teachers are tired. The valuable resource of newly committed teachers should not be lost. LUMA has removed obstacles for teachers and allowed them to experiment and develop their teaching. If anything is to be saved, when support is withdrawn, there should be a strategy ready to sustain this value-added teacher resource.

PROPOSAL 3.1. These points argue the importance of retaining advantages already gained and continuing the good work already begun. One way to ensure this is, that in the appointment of coordinators to continue the dissemination of the LUMA findings, experienced teachers who have built a resource of knowledge and skills be employed to share their findings and help spread their practices (Recommendation B3).

PROPOSAL 3.2. Another way to ensure this is to review the curriculum for Mathematics and Science in the light of the LUMA findings and invite teachers who have contributed to their own curriculum development be involved in the process (Recommendation E1).

Collaboration among Teachers

LUMA generated a teacher-to-teacher collaboration within schools, both among science and mathematics teachers and also across disciplines. This gave powerful support to their team spirit and enthusiasm. It also helped to promote effective learning across different subjects and different stages in school. We judge that this process provides an effective model that could well be developed and implemented more widely.

Teacher-to-teacher collaboration outside the school was another strong feature of the LUMA programme. This was promoted by education/pedagogical/LUMA afternoons, supported by the municipality and/or facilitated by MAOL, BMOL and higher education institutions. These events offered a forum for exchange of ideas, for moral support and for identification of best practice.

Reference has been made in the Report to the study by Irma Aroluoma of LUMA teachers acting as trainers of other teachers. A similar model for support of teacher development has been used to good effect in Ireland, both to extend the teaching of physical sciences to some girls' schools and to provide support for the introduction of new syllabuses.

Inter-school cooperation

Inter-school cooperation is also seen by us as a valuable spin-off from the LUMA programme. The close cooperation between upper secondary school and vocational institutions, which facilitates students to study simultaneously for Matriculation and for Vocational Certificate, is a positive development. It is conducive to the integration of science and technology and to the mutual understanding of joint responsibility of schools to this end. We see cogency in arguments put to us that a 4-year term for this joint study programme would be more realistic than three.

> **PROPOSAL 3.3.** The concept of a 4-year term for an integrated science with technology programme should be fostered; it would be shortsighted/ unfortunate if a too rigorous time limitation were to make this combined study programme unpopular. It has the potential to produce well-rounded and informed students for science and technology study in higher education (Recommendation E2).

It is refreshing to note that the sharing of insights into teaching and learning strategies has not been prejudiced by differences in levels/stages and systems. For instance, valuable tools developed in special teaching have been imported into lower secondary school.

Coordination and Leadership

The role of the school coordinator/contact person in driving the programme within the school and liaising with the municipal coordinator has been seen by the evaluators as very important. The recognition given to this task is not quite clear: it appears that a variety of models were used. In some cases particular teachers were enabled, through reductions in their workload, to develop a specific LUMA activity; in other situations, the school funded (via a municipal contribution) a small reduction in teaching duty for the contact person. In yet other situations the coordinator/contact person worked voluntarily. Yet without this channel to the municipal coordinator – who is seen by us as of primary importance to the programme – the schools' engagement with the programme would have been seriously hampered; in particular it would be of a disjoint nature and against the spirit of the "LUMA tube".

> **PROPOSAL 3.4.** This highlights once again the argument pertaining to the continuance of the activity of the coordinators. The retrospective appreciation of the need for communication and cooperation implies that such coordination is necessary for fostering continued growth within LUMA schools as well as for disseminating LUMA practices (Recommendations B1, B3).

The attitude of the school principal was also seen by us as critical to the success of the programme. In our visits to schools, it was apparent that a non-LUMA school could have a proactive science programme, supported by the principal. As for all aspects of an innovation in schools, the spread of an ethos of science and mathematics learning is dependent on the attitude of the principal to the importance of the programme and his/her help in accommodating non-routine activities that are a natural consequence of innovation. It is not clear to us whether or not it would be fair to say that the LUMA

programme just offered extra impetus to what were already good 'science' schools, given that these were strategically selected in the first instance. Insofar as this might be true, direct use of the LUMA approach in the dissemination to all schools might not be valid.

In-service Training

The major benefit to the whole school system arising from the LUMA programme was the increased availability of in-service training for all teachers. We understand that a generous budget allowance enabled the NBE to give focus to mathematics and science in in-service programmes, allowing degree tuition and short-term courses to be made available across the country. The range and variety of such programmes described in the Report, is appreciated, but it is noted that a true picture of the extent to which this in-service was taken up by teachers in LUMA schools is quite vague (lying somewhere between 11 and 37%). Although LUMA teachers did appreciate the free availability of in-service and the positive benefits of course for themselves and for their schools, there were some misgivings expressed by participants whom we met, about the courses and the understanding by the trainers of the school situation. This would appear to suggest that the objectives set out for the in-service training (Report Chapter 3.7) were not always kept in sight in the selection of courses and providers. The more pedagogically-oriented training provided by MAOL and BMOL, although on a smaller scale, was, in relative terms, better subscribed. In-service training was felt, by those interviewed by Irma Aroluoma for her report, to be "without exception" necessary. But what is equally necessary is the relevance of these courses to the practice of teaching; we understand the concern expressed to us that some of these in-service situations have slow to incorporate the findings of LUMA teachers into their programmes.

> PROPOSAL 3.5. This points to the need for the continuation of an intensive in-service programme and for the adaptation of courses so that they provide the ingredients necessary to encourage change in classroom practice. In particular good practice discovered by LUMA teachers should be drawn into in-service courses (Recommendation C2).

Curriculum

We note with satisfaction the revision of the curriculum involving the re-distribution of classroom hours for comprehensive education. The share of natural science and mathematics reflects its importance in modern education for citizenship and for preparation for further study. This revision will hopefully go some way towards addressing the weaknesses in the achievements in science and mathematics of students entering vocational institutions. The proactive approach of LUMA schools in increasing the weight of science and mathematics in the curricula has been noted.

We are aware of efforts made in LUMA schools to integrate mathematics and science into other subjects. In particular we would favour further attempts to exploit connections between the teaching of the sciences and the teaching of technology. This would address the issue of relevance of curriculum for students in schools by making clear to them the relevance of science to life and modern technology. It would also help

meet a desired outcome of school science, as reported to us in our discussions with teachers in polytechnics, i.e. that the science base of polytechnics entrants should be of a more applied nature.

The importance of building up a strong science base for courses in vocational institutions has been recognised in the objectives of LUMA. The increased science content of the vocational curriculum and the projects supported by the NBE to foster quality teaching and learning should help to achieve this objective. It is regrettable that a follow-up study to those conducted by Wuolijoki (1999) and Saloheimo (1999) has not been undertaken to evaluate these new strategies.

The increased cooperation between vocational institutions and polytechnics could make a strong contribution to raising the level of awareness of opportunities for further education and to ensuring that those students who proceed to higher education are better prepared. However, the critical issue is that students in vocational institutions also benefit from a curriculum that integrates science and technology.

> PROPOSAL 3.6. All of the arguments above point to the need for revision of the curriculum for science; in particular that attention is paid to the balance of science and technology in the design of new curricula in comprehensive education, upper secondary and vocational education; that the expertise of industrial liaison personnel is drawn on for the development of new materials and curriculum support resources. It is important that such resources support the broadening of the science curriculum to reflect the relevance of science to life and modern technology (Recommendation E2).

The provision of equipment to LUMA schools for developing the experimental approach to science teaching was not entirely satisfactory. The evaluators visited an upper secondary school where the equipment resource was totally inadequate. We note that an inventory of equipment in LUMA upper secondary schools was carried out early in the programme; however the follow-up to this seems to have been uneven and unsatisfactory.

The evaluators question the whole classroom design for science teaching in upper secondary schools, noting that the existing plan of a classroom partially adapted for peripheral practical work does not constitute a suitable environment. The curriculum objectives for Physics in upper secondary include the objective that students develop the ability to carry out simple experiments on natural phenomena; the classroom design seen by the evaluators would lead us to question how this objective can be achieved particularly with large class sizes. The use of ICT can go some way to providing a practical element to teaching and the new programme to equip teachers with necessary ICT skills is welcomed. However the use of computer simulation by students cannot develop in them the skills set obtainable from handling equipment and designing real experiments. It would be interesting to know what emphasis was given to this practical aspect of science teaching in LUMA schools with the equipment provided for the programme.

> PROPOSAL 3.7. These arguments together with those made in Chapter 4 (on Assessment and the Curriculum) point to the need to clarify the position on

practical work in upper secondary science, and to identify the parties responsible for resourcing it from the point of view of capital needs, maintenance and technical assistance (Recommendation E3).

A basic requirement for increasing numbers taking advanced courses in mathematics and science is that these courses are attractive to students. So it follows that a key question is: Are students' attitudes to the sciences positive? Given this, we find it disappointing that no attempt was made in the LUMA programme to survey the attitudes of students to the study of mathematics and science. In particular, this would have added significant weight to the qualitative reports on new enthusiasm in the classrooms if trends in students' attitudes to science could have been recorded in the LUMA schools and compared with those in non-LUMA schools.

PROPOSAL 3.8. This observation reinforces the argument made in Chapter 6 for adequate research into the attitudes and motivations of students (Recommendation G1).

Quantitative Targets

The open design of the upper secondary curriculum may militate against the expansion in numbers taking mathematics and science at this level. Irma Aroluoma noted in her report that recruiting students is difficult in the non-graded, modularized system. We believe that the significant percentage of students taking advanced courses in Physics and Chemistry could be augmented (or prevented from declining further) if timetabling and the general logistics of the graded system were carefully examined. The quantitative objectives set for increasing numbers taking advanced courses in the sciences at upper secondary may have been unrealistic, considering that LUMA students comprised only 11-12% of the national total of students involved, and also considering the slow dissemination rate of the LUMA practice. However, it is pertinent to ask, aside from LUMA, if the conditions are right for increasing uptake. For example, one might ask whether students are helped and encouraged to take advanced courses in mathematics and the natural sciences by more favourable timetabling arrangements. If dissemination is to be successful, there is need to ensure that there are no serious timetable constraints; in fact, building up Science and Mathematics may initially require an ex-quota allocation of resources e.g. by the provision of advanced courses even if numbers are low.

CHAPTER 4

EXAMINATIONS AND ASSESSMENTS

The structure of the matriculation examination

The current form of the matriculation examination has features which set up significant obstacles to the realisation of the LUMA objectives. The way in which the different papers are partitioned, and the range of choices available to students mean that they can avoid answering any questions on the physical and biological sciences, whilst the choices for mathematics also mean that they can avoid questions in the advanced mathematics also. We note that the large number of questions in the general paper as a whole is such that students will be well advised to choose beforehand the sections from which they will select questions.

We find it hard to believe that the system does not have an effect on the study efforts of students in the year leading up to the matriculation examination. It seems likely to us that students will be choosing their subjects for tertiary education well before the examinations: a check on this hypothesis ought to form part of any evaluation of this examination system. Given that the data for the 2001 examination show that only 11% of the entry answered five or more questions in physics, and only 24% at least one question, with corresponding figures of under 2% and 14% in chemistry, such effects could be serious in their impact on recruitment to more advanced study in these subjects. However, it is hard to take this argument further in the absence of the results of research into the views of students about the effects, of the choices offered, on their priorities for their study in the upper secondary, or on the strategies they use in tackling the general paper. It seems strange that these issues have not been explored.

Apart from the effects of this structure on the commitment and motivation of students, it also means that the examination results may give little or no information on the achievements of many students in mathematics and the sciences, so that monitoring of the progress in the learning of these subjects across the country cannot be carried out. (we note that to meet this need it has been necessary to conduct an ad hoc survey for the third year of upper secondary education in physics and chemistry, for which results are awaited). In this respect, we have been unable to find whether or not results for work in the separate sections of the general paper are separately available for individual students, and whether, if available, they record the numbers of questions attempted in each section. Given the small numbers of questions that students may choose in the sciences in the general paper, the reliability of the results will in any case be very low, i.e. there will be a high probability of mis-classification due to the variabilities inherent in drawing on only a small sample of the students' work.

The university entrance examinations

The setting by universities of their own entrance examinations is understandable in view of these limitations of the matriculation examination. We note that universities have been moving towards collaboration in setting a common examination in each subject. However, the net outcome is that schools and their students have to work to two different sets of targets, i.e. the matriculation examination and the university entrance tests. This increases the examination pressures on the work of teachers and their students. At the same time, it follows that, given that the curriculum actually taught will be driven by test pressures, school studies are being driven by those in the universities who set the entrance examinations, rather than by the wider range of public interests that ought to be represented in decisions about the curriculum. This would be unacceptable in most of the countries of which we have experience.

> PROPOSAL 4.1. The effects on students' attitudes and study choices of the present structure of the general studies paper in the matriculation examination, and the likely effect on them of changes in this examination, should be investigated (Recommendation F1).

The issue to be explored therefore is whether a combination of matriculation examinations, in a revised structure, together with schools' own assessments can provide the information that universities need so that their separate examinations are unnecessary. For the examinations this would call for separate tests for each subject area, with results separately reported by subject. Whether these, or some more modest assessments, should be taken by all students irrespective of their plans for their future education is a matter for discussion. However, if students have worked at the sciences, we judge that there should be some nationally attested record of their achievements even although they have not chosen to make such studies their first priority. We only point out that whilst an understanding of mathematics and the sciences adequate to enable them to understand their effects on their lives as future citizens may be provided by age 16; many countries also provide for subject specialisation beyond age 16 for those students who wish to do so.

Assessments by teachers and schools

We could not get a clear picture of the formulation and the use of each school's own reports on the achievements of their students. Some degree of uniformity of practice is essential here to ensure that judgments are comparable across schools, for otherwise future employers and university selectors cannot place much weight on them. We understand that there are no measures at present to ensure such comparability across schools.

Similar concerncs arise in relation to the assessments of their pupils made by schools at the end of basic comprehensive education. Here there is also a competitive situation in many regions, because selection for entry to the more popular upper secondary schools, and between upper secondary and vocational schools, is based on the schools' assessments. Again, the issues of comparability across schools in the criteria, procedures and standards used seem important, and yet we could not find evidence of work on this comparability. We note the criteria for the assessment at the end of basic education

(Annex 5) , but understand that it is left entirely to schools to interpret these in terms of actual evidence of achievement.

> PROPOSAL 4.2. The arguments in the two sections above point to the need for further re-appraisal, both of the matriculation examination and of the assessment by teachers and schools of their own students. However, given the inevitably close links between assessment and the curriculum, implications for the curriculum also need consideration (Recommendations E5, F1, F2, G1).

Assessment and the curriculum

The criteria specified for assessment at the end of basic education do mention practical skills, investigative study, and problem solving, but our own experience is that without some system of external monitoring a serious implementation cannot be assumed. Indeed, if these criteria were already being taken seriously by most schools, several aspects of the LUMA programme would seem to have been un-necessary. The setting up of a task bank in mathematics to help improve teachers' assessments in basic education could have helped improve comparability, so it seems unfortunate that sales have been so limited and that teachers' use of the bank has not corresponded to the original intention. This seems to call for investigation of the assessment skills of teachers who are responsible for the assessments at exit from the basic schools. Furthermore, the reported poor performance of pupils on the tasks in this bank seems to call for further investigation of the level of pupils' performance at the end of basic education and of teachers' awareness of this issue.

We also find no evidence that some of the aims specified for basic education are reflected, for the next stage, in the matriculation examination. The difficulty is that some of the important aims of education, not least in science and mathematics, cannot be tested by short written tests however carefully designed. A notable example here is practical work in science, both at the level of component skills and in work by students on practical investigations in which they are given responsibility to design, carry out, and evaluate their own attack on a problem. Experience in several countries has shown that attempts to assess the skills and strategies involved by written tests cannot produce a valid result. Thus the only way to assess these aims is for teachers to make the assessments, for then each student's work can be in a valid context and relatively free of time constraints. There is then a substantial task in setting up monitoring systems to ensure comparability between teachers across different schools, so that these 'practical work' results can form a percentage in the final matriculation subject mark. Experience in other countries has shown that only with such a system will teachers and students be motivated to take such work seriously.

Similar arguments apply to other important aspects of education in mathematics and the sciences. The solution of complex everyday problems, whether in mathematics or at a theoretical level in the sciences, and the formulation of extended essays based on library research are relevant examples. Developments which add significance to these aspects of education are important for the validity of teaching and assessment in the LUMA subjects. However, they are also important in respect of the aim to enhance the motivation and commitment of students to the study of these subjects. Again experience has shown that many students are attracted by these more open and

engaging aspects of the subjects. Indeed, it could be argued that if teaching is largely confined to the formal study of the theoretical concepts and the techniques of the mathematics and the sciences and is devoid of engagement in the application of these to real problems, the student will have no realistic experience of the nature of the disciplines – and cannot be expected either to be attracted to them or to choose wisely for their further study. So it seems necessary to create some pressure for teachers and schools to take these aspects seriously, and to have a system that rewards students achievements in them through the matriculation examination.

These issues are as much curriculum issues as assessment issues, but comprehensive appraisal of the curriculum in relation to these aims has not formed part of the LUMA programme. The report of the 1999 test survey by Rajakorpi indicates that pupils had a poor command of tasks relating to measurement and to in-depth handling of information and problem solving. Given that the same survey indicated little difference between the results of LUMA pilot schools and the control schools, it seems that the project has failed to make an impact at upper secondary level in this important area. The absence of any assessment requirements, which could both exemplify desirable practice and stimulate a shift in the style and priorities of teaching, may well be a factor here.

> PROPOSAL 4.3. The issues raised in this third section of this chapter point to the need for a re-appraisal of curriculum aims and of the way they are supported in assessment systems (Recommendations E3, F1).

CHAPTER 5

UNIVERSITIES AND POLYTECHNICS

Recruitment, entrance, and funding

One of the goals in the LUMA programme has been to increase the number of students in tertiary education in mathematics, the sciences and technology. This quantitative goal has been reached and, in fact, even surpassed. We have also noticed that there is a trend to a higher percentage of female applicants to LUMA fields in polytechnics but that the percentage of female entrants is slow to rise. This raises the question about efforts to correct gender bias.

There is a serious recruitment problem in tertiary education, which Finland shares with other countries. This is the decline of the level of mathematical skill and knowledge of beginning students as reported in the Final Report of the Project "Development of University Education in Mathematics and Exact Sciences via Trilateral Co-operation, Finland-Hungary-Sweden", and the corresponding report on chemistry. Many of the beginning students do not have the mathematical preparation needed to reach the final goals of their tertiary education. One reason for this difficult and complex problem is undoubtably today´s mass education where many more students than earlier take part in tertiary education requiring a lot of mathematics. Measures must be taken to identify the various reasons for this problem and to take constructive action to tackle it. Such analysis and action will call for co-operation between many partners. We note that projects related to this problem have started, not only in mathematics but also in the sciences (LUMA Report, Annexes 15, 19, and 20). For instance, adjustments have been made to the teaching and to the first year syllabuses to accommodate to the changing standard and the wide spectrum of knowledge, background and interest of incoming students.

> **PROPOSAL 5.1.** Measures should be taken to try to understand, and to do something about, the reasons for and problems with the decline of the level of mathematical skill and knowledge of beginning students (Recommendation E4).

Today universities and polytechnics in Finland use entrance tests. There may be different reasons for this but one reason is obviously that the examination/assessment at the end of upper secondary and vocational schools is not considered to be adequate.

> **PROPOSAL 5.2.** We recommend a reform of the matriculation examination which could decrease the need for entrance tests (Recommendation F1).

In Finland the annual number of masters´ theses is the most important factor for the funding of undergraduate teaching. This is a big problem at least for the departments of mathematics since these receive an almost negligible amount of financial support for their very extensive service teaching. This is a serious threat to the quality of their teaching, and it also means that there is not time enough for the contact needed

between students and teachers. We have heard evidence that the students suffer from this and that it causes delays and failures in their studies It would certainly increase the quality of the mathematics training if the departments were adequately paid for their amount of teaching, which should be measured by the numbers of students and credit points actually taught.

> PROPOSAL 5.3. We recommend that the funding of the departments is changed so that the number of students and credit points actually taught is taken into consideration (Recommendation I2).

Academic teaching and LUMA

It is our general impression that the university teachers in the LUMA subjects are highly qualified and that the curricula in LUMA subjects meet the best international standards. For university teachers it is, of course, natural to stress the academic tradition of their subject. However, in order to increase the students´ interest in mathematics and the sciences it is also important in undergraduate education to stress applications and reflect more on uses in business and industry. Concerning the subject of mathematics it must also be remembered that mathematics for many students is seen primarily as a service subject for their further education, and this must have influence on the curriculum and the teaching. Furthermore, university teachers should have a reasonable information and knowledge about future job opportunities for students and about the manpower needs of industry. We are not convinced that teachers are adequately informed in these aspects at present.

> PROPOSAL 5.4. It is essential that the undergraduate courses reflect more strongly the uses of science and mathematics in business and industry (Recommendation E2).

We saw and heard about examples of open universities in Finland. The idea of an open university is a natural part of LUMA. It is recognised in our own countries that the setting up and effective operation of open university programmes demands very special skills and attention, both to hardware, to the nature of the software programmes, and, most demanding of all, to the modes of teacher-student and student-student interactions that will work well in promoting learning. Given the complexity of these requirements, we are surprised to find that efforts are duplicated across many centres.

> PROPOSAL 5.5. We recommend that national collaboration between the open universities be initiated as soon as possible (Recommendation D).

As a natural part of the LUMA spirit of cooperation, it is very desirable that universities/polytechnics find voluntary ways to work with schools and for schools. For instance, summer schools for pupils/students and visits to schools by university teachers to talk to pupils/students are good ways to increase interest and to attract new students to the areas of mathematics and the sciences. Another example is in-service training of class teachers and subject teachers in order to develop their knowledge of mathematics and the sciences.

PROPOSAL 5.6. We recommend that tertiary level teachers take active part in in-service training of teachers in school (Recommendation C2).

The annexes to the Report describe many projects in the LUMA programme in which the universities and polytechnics have been involved. Our conclusion is that the programme has made universities and polytechnics responsive to the need for contacts with schools. It is, however, obvious that the engagement among tertiary level teachers for LUMA ideas is very variable. For polytechnics as a whole, LUMA does not seem to have been a big feature, but individuals and various polytechnics co-operate with schools and with LUMA activities.

PROPOSAL 5.7. Each department/faculty and university/polytechnic should make arrangements to ensure that contacts with schools are continued and that opportunities for dissemination of LUMA ideas are fully exploited (Recommendation C2).

Teacher education

The role in school of the teachers is crucial to the recruitment of students to mathematics and the sciences, and to the provision for these students of a good preparation for their studies at universities and polytechnics. Consequently, the training of future teachers is extremely important, and it is also desirable to increase the status of teachers in order to attract good students to this occupation. There has been a re-assessment of the weighting of mathematics and the sciences in the courses for teacher training. Different models have been developed for increasing the subject knowledge of class teachers and of subject teachers during their training (e.g. reformed curricula, minor subject modules, multidisciplinary studies). We also note that targets have almost been reached for the number of subject teachers produced per year.

The relation and co-operation between subject departments and educational departments are essential in teacher education, both of subject teachers and of class teachers. It is a complication when different departments and even different faculties are involved - the staffs probably do not meet in the same coffee room, and it is often not clear which department and which faculty is responsible for the content and teaching of the separate courses. We have the impression that LUMA has meant something positive here but that more should be done.

Here are some examples. Co-operation is needed to design a course to serve the subject needs of the future subject teacher, and this holds also for a course for the future class teacher. In subject courses for future teachers it is especially important to stress motivation and understanding by means of the history of the subject and applications from other scientific areas and from real life. It is also essential to discuss questions specially related to the pedagogy of the subject (subject didactics) since this will better prepare the future teachers to understand the learning difficulties of the pupils/students. Furthermore, we mean that tertiary level subject teachers of mathematics and the sciences should know more about educational aspects, and that teachers at educational departments should know more about subject aspects.

In our view it follows that more masters´ theses by future subject teachers should be written on topics related to educational problems, for instance educational problems concerning the main subject of the future teacher, rather than on pure subject topics. We have heard different explanations why so few masters´ theses are written on educational topics by future subject teachers. One reason may be that the staff in educational departments have too little time for research and are therefore less inclined to getting involved as mentors for masters´ theses.

> **PROPOSAL 5.8.** Masters' theses by future teachers should usually focus on an educational theme (Recommendation C1).

> **PROPOSAL 5.9.** There is a need to strengthen research capacity in areas of relevance to the pedagogy of mathematics and the sciences (Recommendations C2, G2).

We also stress that it is desirable that teachers at school level are given the opportunity to take an active part both as assistant mentors for masters´ theses and in research projects. Of course, cooperation between subject and educational departments is also important, both in research projects and in the work of mentoring masters´ theses. We saw good examples of such co-operations during our evaluation visits but this good practice needs to be taken up more widely.

> **PROPOSAL 5.10.** We recommend increased co-operation between lecturers from subject and educational departments (Recommendations C1, G3).

CHAPTER 6

RESEARCH AND EVALUATION

There are several ways in which research could play a part in a broad and ambitious programme such as LUMA. These are:

(i) Help in the design and implementation of the programme by providing initial intelligence.
(ii) Form an intrinsic part of the programme through targeted research projects.
(iii) Evaluating the programme, either for feedback during its progress or for final evaluation.
(iv) Form an intrinsic part of the programme in the building of research capacity for the future.

In this chapter, each of these will be discussed in turn, and this will lead to some closing reflections.

Initial intelligence

For several of the aims of the programme, for example in encouraging greater participation of girls or in raising interest and motivation for mathematics and science amongst all students, there exists a substantial international literature which could help to clarify the nature and possible causes of the problems, and thereby suggest strategies for tackling them. It follows that reviews of such literature might have provided a starting point and guidelines for the various projects. We have seen no evidence that such reviews were undertaken or that results of previous work, either in other countries or in Finland, were taken into account in any systematic way.

> **PROPOSAL 6.1.** That such research reviews be commissioned so that they will strengthen the interpretation of the LUMA findings and the basis for decisions about future development (Recommendation G1).

Research component of the programme

The programme – MALU – of the Academy of Finland – seems to have been the relevant element here. We note that this programme had to be funded from the Academy's normal budget so that it had to compete with other demands. The fourteen projects that they funded were classified in three groups. For the first of these, grouped as *Mathematics, physics, chemistry and information technology in schools*, two directly addressed research into problems of learning, of the other two one was developmental concerned with learning materials, the other with an internet magazine.

For the second group, focussing on the same issues as the first only for universities, two were for research on learning issues, two developmental on mathematical methods and

modelling, and one on computer use for mathematics studies.

In the third group, five projects grouped as *Mathematical Models*, seem to us to be research projects in modelling having no direct relevance to LUMA. The same seems to be true of the Academy's second programme on mathematical models and methods in different branches of science (MaDaMe).

We note that the biological and geographical sciences did not feature in this programme. Taken together, the four studies concerned with learning might have formed part of a coherent programme of learning research. The other five in the first and second groups do not seem to form a coherent programme in development of curriculum materials and methods.

We have looked also at the work in the University of Jyväskylä Institute for Educational Research. In their presentation to us, the staff chose to give strong emphasis to their analyses of the international comparisons produced by the TIMSS and PISA programmes. We find it hard to understand why these comparisons received such priority, given that they provide little information that can be useful in programmes to improve educational outcomes rather than merely to measure them. We were informed subsequently that the Institute is conducting other educational research projects and in particular was responsible for oversight of the relevant research of Irma Aroluoma. Given that such projects may well have been directly relevant to the evaluation of the LUMA programme, the main purpose of our visit, we would have liked to hear more about them.

We have been impressed by the research programme of the Research Centre for Mathematics and Science Education in the Department of Education of the University of Helsinki. The balance between fundamental research and work on practical developments, and the development of co-projects with the Departments of Physics and Chemistry are evidence of a well-planned strategy. In a more specialised area, the research programme of the Niilo Mäki Institute also seems to be making a valuable and well directed contribution.

Overall the research and evaluation projects directly promoted by the LUMA do not form a strong or coherent programme. This seems to have arisen in part because the MALU projects arose as a selection from diverse proposals rather than as a coherently specified programme. Given that the resources were slender, it seems unfortunate that a significant proportion was devoted to projects of little relevance to the LUMA objectives. We can only draw attention to the fact that, as the examples in the previous paragraph illustrate, there is capacity in the country to formulate and implement well directed and relevant work.

> PROPOSAL 6.2. There should be an audit of current research programmes in education, in universities and in other institutions, in order to evaluate their likely contribution to policy and practice in the future. At least some future funding should give preference to studies which are designed to deliver such contributions (Recommendation G3).

Evaluation studies

The final Report from the LUMA support group constitutes a significant evaluation of the project. It reports both statistical data available from the various institutions, and qualitative accounts of the various projects. Both of these sources inform a review of the achievement of the several objectives. We comment on the pattern of successes and failures in Chapter 8 below. The relevant issue here is that we have not found it easy to understand this pattern, and this difficulty is due in part to the absence within LUMA of any systematic set of in-depth evaluation studies.

The only study of this type seems to have been that carried out by Irma Aroluoma. Her findings throw light on a pattern of commitment of teachers ranging from enthusiasm to disseminate to 'being tired'. The evidence of an uneven pattern of support for teachers across the municipalities was a strong feature, and it is clear that the loneliness of some teachers in trying to develop a renewal of their work would need careful attention in future. Given that the future depends on proper support of dissemination, there would seem to be a need to evaluate, in order to understand, the processes and decisions made by the municipalities in promoting LUMA. We also draw attention to the lack of any direct evaluation of pupils' responses

For the university level, the reports arising from the collaboration with Hungary and Sweden provide some useful information. For Finland, these are limited to self-evaluations by one department of chemistry and two of mathematics. These report useful descriptions, enriched by the cross-national comparisons, of the strengths and problems in the existing pattern of research and teaching in the departments concerned. However, there seems to be no discussion of initiatives for change sponsored, or supported, by the LUMA programme, no account of the processes of change, and no accounts of inquiries about the effects on students, either in the main subjects or in teacher training.

Useful information about the co-operation between upper secondary schools and universities was provided by the 1998 work of the LUKO group and of the National Board of Education's 1999-2000 work group. The reports of the municipalities provide a further perspective – we note that it is only in this set of reports that the links between the vocational school and the polytechnics are described. There is no report, however, of any survey of the reactions of school pupils to the various initiatives, which seems unfortunate given that one of their main aims was to enhance motivation and future choices by these students.

> **PROPOSAL 6.3.** This reinforces our earlier plea for research studies of the factors which affect the attitudes and motivations of school students toward science and mathematics (Recommendation G1).

Building research capacity

Here the concern is with supporting the development of trained researchers and with exploiting the experience and expertise of those already engaged in research. The aspects of the programme already discussed above could have made a strong impact here, but we judge that given the small proportion of the resources devoted to these

aspects such an impact could not be achieved.

The initiative to support graduate programmes leading to grant support for researchers trained through doctoral work was a welcome development. The use of a co-ordinated network promises well for the effective use of limited resources. However, we question whether rotation of the identity and the location of the co-ordinator between different departments is a good one. The distribution of the limited numbers of grants across several departments seems too great a dilution of effort. With only a handful of doctoral students in some of the departments, the opportunities for their students to learn by interaction with one another and with experienced researchers who span a range of interests and methodologies will be very limited. It is also hard, with small groups, to provide the range of systematic courses in research design, and in methods for collection and analysis of data, which current research requires. There ought to be an ambition to build schools of world class research, and it might better serve the needs of a small country to attempt to do this by concentration of resources in only one or two centres – which might eventually become beacons for the rest.

One avenue which would repay development would be the active involvement of school teachers in research, whereby they become collaborators and not mere objects of research. This would both help make the research more directly applicable to everyday practice and lead some experienced teachers into research careers, albeit on part-time basis.

> **PROPOSAL 6.4.** These several arguments all point to the need for a programme to strengthen research capacity for the future. There should be concentration of resources for research and research training in two or three centres of excellence (Recommendation G2).

Reflections

Overall, the research dimension of the LUMA programme has been uneven in its achievements. This has arisen in part because the resources have been spread over several initiatives without a strong and clear unifying programme. Across the four areas discussed above, the outcome might have been stronger if resources had been concentrated in a programme with a clearer overall strategy.

CHAPTER 7

THE CONTRIBUTION OF INDUSTRY

By tradition and for obvious reasons business life and industry (in which term we include non-industrial businesses) have always had contacts with vocational schools and polytechnics. Today, when technology and natural science are coming closer to each other, it is necessary to increase contacts also between industry and universities.

In the public debate preceding the LUMA programme business and industry took an active part and, in fact, were influential in initiating the discussions that led to LUMA. During the LUMA period industry has organized science and technology camps for children, national and local training events, and summer job campaigns. Industry has a long term commitment in education which is planned to continue even if the LUMA programme is terminated. They have a deep commitment to the strengthening of Finland´s identity as an industrial nation. This is a very positive factor which should be supported and used in the future. However, there are also difficulties in the contacts with industry in the LUMA programme. According to a report by Irma Aroluoma industrial groups usually had a very positive attitude towards the LUMA programme during the initial discussions, but in the end avoided becoming too much involved.

During our visits we also had the opportunity to meet representatives from business and industry. Their view is that quality in education is more important than the quantity of content. In particular they stressed the necessity to develop in students

- thinking skills
- oral and written communication skills
- initiative and self-esteem and
- the ability to work in groups.

We agree that these four items are important in education but, unfortunately, our experience is that they rarely command adequate space because of lack of time, both for students and for teachers. Thinking skills may be developed by creative problem solving in which learners work on problems which are not routine applications of standard procedures. Oral and written communication should be systematically practised during education. Training to work in groups is important both to promote creativity and to prepare students for their future working life. Development of students´ powers of initiative and self-esteem are among the most important aims of education.

Furthermore, the representatives of business and industry stressed that the students´ knowledge of particular content of subject courses is not so important for industry. They do want more contact between students/teachers and industry and point out that such contact is important for industry, for students´ future work, and to enrich their reflections on their education and its role in society. A more regular contact between industry and teachers at all levels would increase their knowledge of each other and would promote mutual understanding. This would also be of help in the counselling of

students during their courses of study.

Today business life and industry have a broad interest in education, from pre-school level to university, polytechnic and the open university levels. They support education and educational projects both financially and in other ways and will continue to do so.

> PROPOSAL 7.1. We recognize the contribution by industry and recommend that they become more involved in the educational process and that more attention is paid to their needs. In particular, industry should be consulted about the curriculum in the future (Recommendations E1, H).

CHAPTER 8

THE PROCESS OF THE LUMA PROGRAMME

Some reflections on the process of LUMA will serve to draw together the observations raised in the preceding chapters.

The rationale was for *joint action*. This gives the initial impression of an implementation process that was diffuse and uncoordinated. However, whilst we appreciate the concept and recognise the freedoms that are involved in this approach, we see both advantages and disadvantages and so we offer the following observations on the organisation and implementation of the programme.

Freedom and Diversity

The approach of inviting stakeholders – municipalities, universities, industry, teacher groups – to take action, each essentially to their own design, with limited imposition of a mandated framework appears to have evoked and secured a strong commitment from some players. Thus the approach was bottom up rather than top down, and few serious constraints were imposed on those undertaking an initiative of their own choice. On the other hand however there was little coercion into action. This strategy allowed genuinely interested parties a sense of ownership of the process, although the decision to select 'good' schools as pilot schools would also have helped ensure a good level of commitment to, and participation in, the programme.

The encouragement of the growth of clusters and networks was another positive aspect of the implementation. Cooperation between teachers, schools, industry, and higher education institutions, led to a wide range of projects addressing objectives related to vocational education, gender issues, in-service, special support, curriculum development and so no. The crucial role played by the municipal coordinator in these processes has already been examined in our Chapter 2.

Support and Coordination

The two coordinator roles, both municipal and in-school, were, in our view, compromised. Good in-school coordinators, with reasonable time allowance to attend to the responsibility, could have ensured that their schools would be fully-participating pilot schools. Responses gathered by Irma Aroluoma from teachers suggest that the level of coordination required to generate a group momentum was absent in some cases: "they felt that they were left to their own devices with many matters: the focuses of the curriculum and distribution of classroom hours, work arrangement, getting pilot ideas approved by municipalities and schools, resource allocation talks and the obligation to disseminate the projects as well as authorizations". It is noted that, out of 78 participating municipalities, a total of 56 submitted reports to the LUMA Support Group in February 2002; the lack of sufficient recognition and support for the

coordinators may go some way to explaining the less successful situations from which reports were not forthcoming.

Pilot Municipalities

Despite the strong commitments reported directly to us, there is the evidence from the evaluation undertaken by Irma Aroluoma of differing commitments of municipalities and schools across the regions investigated by her. Respondents quoted the lack of moral support as a factor contributing to poor commitment of teachers: "a group was better able to undergo training, operate at its own school and disseminate the Project than teachers working on their own". This raises a question about the weakness inherent in the autonomy given to municipalities. Thus we are led to wonder whether some may have given insufficient moral and other support to their schools, whether some could have done more to encourage schools to participate, and whether some might have passed over enthusiastic schools that might have wished to be involved.

Funding

In our view, the funding for the programme was possibly too modest. For such a broad programme, operating at so many levels, we have the impression of severe constraints imposed by limited resources, compensated for by goodwill and voluntarism. The budgets allocated by municipalities varied considerably. This had implications for the critical role of municipal coordinators and for, in some instances, the purchase of equipment for upper secondary schools. Also financial support by school managements for in-school projects varied. In this regard some non-LUMA schools visited by the evaluators had more proactive support by principals for their science programmes. We were advised by teachers we met that more money and more time could have made a significant difference to their efforts to advance the project in their schools. Teachers and schools appear to have taken full advantage of the funding provided by the National Board of Education for in-service training, but nevertheless we heard reports of some teachers having to bearing themselves the costs of some of the professional development activities. It may be significant that the area to which the largest share of funding was allocated i.e. higher education, was the only area that came close to meeting the targets set for it, i.e. in meeting the target numbers for those students starting courses and for those graduating with MSc in universities and polytechnics.

Coherence

One weakness in the planning of the programme was the failure to identify issues before embarking on action. There was little or no research undertaken to guide the programme, and no preliminary systematic identification of weaknesses in structures and processes. Such identification could have helped to ensure that measures were designed to address key problems. On the whole, the opportunity for education departments and research institutes to cooperate and communicate on issues related to the programme was overlooked. Procedures for innovating the practice of science teaching and learning, established and tested in many countries, could have been examined against the perspective of the Finnish education environment, and the findings used to inform a strategy.

There appears to be no system in place for collating the information on new initiatives arising from LUMA activities in schools, e.g. in initial teacher training and in-service training, and channeling this back for analysis. Broad templates could possibly have been devised so that outcomes from various stakeholders could have been analysed to decipher broad guidelines for best practice.

The funding by MALU was dispersed over a range of projects, some not at all associated with the objectives of LUMA. The rationale for this approach adopted by MALU has been explained to us but our judgement of this is that another opportunity for the synergy of research and action was missed.

Cooperation

A positive feature of the programme was the encouragement of communication and cooperation across traditional boundaries: schools, vocational institutions, polytechnics, universities, industry. Communication between schools and higher education institutions provides a necessary perspective for teaching staff in universities and polytechnics to assess the appropriateness of their courses for first year undergraduate students, as well as breaking down barriers that might exist in the attitudes of school students towards higher education. Links between schools and industry can likewise expose students to the reality of technology in society and can enable valuable experience from industry to inform curriculum innovation. Continuation of both strands of communication is a good investment for school science and for recruitment to science and mathematics courses in higher education.

Dissemination

Dissemination was intended to be a key component of the programme. However, there were no guarantees built in to the process to ensure that this dissemination would take place. Most schools were not in the programme, but there was no system in place to allow flow of information from LUMA schools to these other schools. MAOL used their in-service to help this flow. Websites and e-mailing lists contributed. But it does not seem to us that anyone was given overall responsibility for promoting and co-ordinating these dissemination activities. The spread of information on activities would have provided a good sounding-board for teachers to enable them to evaluate their own new ideas. Critical information for the advance of projects may not have been passed on. For example the Jyväskylä Vocational Institute of Technology have secured ESF funding for a LUMA-type project; this is a good model that should be advertised.

In this closing stage of the programme, no framework seems to exist for continuing the dissemination. Valuable know-how has clearly been gained but it seems destined to remain more-or-less locked in the LUMA domain. Dissemination has not yet occurred on any significant scale because of lack of resources and it will not happen without a concerted effort to promote it. The targets set for the numbers of students taking science and mathematics in matriculation cannot be expected to be reached until there is adequate support for the spread of LUMA practices to non-LUMA schools.

In summary, we acknowledge that the strategy adopted for the programme has avoided the retrictive effects of top-down innovation that have been experienced in many other countries – not least our own. However, we judge that the programme went too far in eschewing any centrally directed co-ordination, and that in consequence the admirable investments of enthusiastic effort made by many of those involved may not yield their potential value for the country as a whole. In this respect we are particularly concerned that unless there is a determination to compose and pursue a strong programme of dissemination, much of the effort invested in LUMA may turn out to have little of long-term benefit.

> PROPOSAL 8.1. We recommend that a new initiative for the dissemination of the practices and other valuable outcomes of the LUMA programme be formulated and implemented as soon as possible (Recommendation A).

RECORD OF THE VISITS AND CONSULTATIONS OF THE EVALUATION TEAM DURING THEIR WEEK IN FINLAND FROM 30TH SEPTEMBER TO 4TH OCTOBER

Monday September 30th

09:04 – 12:36	Train from Helsinki to Jyväskylä Negotiations and planning in the train together with some LUMA people from the NBE (project coordinator Antero Hietamäki, councellor of education Jari Koivisto, chief technologist Lauri Kurvonen, senior adviser Leo Pahkin)
13:15 – 15:15	Visit to Jyväskylä Vocational Institute of Technology (director Hannu Salminen, director of education Anne Melasalmi, lecturer Birgitta Mannila and others)
15:30 – 17:00	Visit to University of Jyväskylä, depts. of physics, chemistry and biological and environmental science by Paul Black (dean of the faculty of science, prof. Matti Manninen, prof. Veikko Huhta, prof. Jukka Maalampi, university lecturer Juha Merikoski)
	Visit to University of Jyväskylä, dept. of mathematics by Hans Wallin (prof. Pekka Koskela and many others, including prof. Tommi Kärkkäinen from the Faculty of Information Technology)
	Visit to Jyväskylä Polytechnic, Schools of Engineering and Technology and of Information Technology by Aine Allen (vice president Eero Suosara, director Petri Maaranen, head of programme Esa Salo, lecturer Markku Korhonen)
17:15 – 19:00	Visit to University of Jyväskylä, Institute for Educational Research (director, prof. Jouni Välijärvi, prof. Päivi Häkkinen, senior researcher Pekka Kupari, researcher Pasi Reinikainen, researcher Jarkko Lampiselkä)

Tuesday October 1st

08:30 – 09:40	Meeting at City of Jyväskylä Education Department (director of education Markku Suortamo, development manager Harri Nissinen, lecturer Irma Aroluoma, announcer Merja Larkkonen, special teacher Juha-Pekka Nuutinen, lecturer Helinä Patana, director of day care centre Sirkka-Liisa Pylvänäinen, principal Anna-Maija Risku), representatives from the neighbouring Rural District of Jyväskylä (Jyväskylän maalaiskunta) were also present (head of education Kauko Roikola and lecturer Anna-Maija Pölkki)
10:00 – 13:00	Visit to Neulaskangas day-care centre, which provides pre-school education, by Hans Wallin (Markku Suortamo and Sirkka-Liisa Pylvänäinen)
	Visit to Huhtarinne special school for children with physical disabilities, neurological and other long-term diseases by Aine Allen (Harri Nissinen and deputy principal Liisa Riikonen)
	Visit to Cygnaeus general upper secondary school by Paul Black (principal Ari Pokka and Irma Aroluoma)
13:00 – 16:30	Visit to the Jyväskylä Teacher training school and discussion with representatives of the dept. of teacher education, teacher training school and Niilo Mäki Institute (admin. director Pekka Ruuskanen, principal Sari Nissinen, principal Helena Muilu, university lecturer Tuula Asunta, clinical neuropsychologist Pekka Räsänen and others)

17:00 – 20:56 Return to Helsinki by train
Negotiations in the train (Antero Hietamäki, Jari Koivisto, Lauri Kurvonen) including discussion with Irma Aroluoma about her study on LUMA schools

Wednesday October 2nd

09:00 – 12:00 Meeting with the LUMA Support Group at the Ministry of Education, chaired by the Group's vice-chair, Permanent Secretary Markku Linna

15:00 – 16:30 Meeting with representatives of the Ministry of Education (special government advisor Mirja Arajärvi, senior adviser Maija Innola, councellor of education Raija Meriläinen and senior adviser Jari Rajanen) and Finnish Higher Education Evaluation Council FINHEEC (senior adviser Anna-Maija Liuhanen)

Thursday October 3rd

08:30 – 11:30 Visit to Tapiola school and Olari school for years 7 – 9 of basic education at the City of Espoo by Aine Allen (deputy principal Heikki Pihkala, deputy principal Maija Flinkman and others)

08:30 – 11:30 Visit to Töyrynnummi school for years 1 – 6 in Helsinki and to Hyökkälä school for years 7 – 9 of basic education in Tuusula by Paul Black (principal Jaana Heporauta, principal Matti Valkonen and others)

08:30 – 11:30 Visit to Helsinge gymnasium and the Helsinki mathematics upper secondary school (Maunulan yhteiskoulu) by Hans Wallin (principal Mikael Hakola, principal Jouko Jauhiainen and others)

12:00 – 14:00 Meeting with representatives of The Chemical Industry Federation (Kemianteollisuus ry.) (deputy director Riitta Juvonen), The Federation of Finnish Electrical and Electronics Industry (SET ry.) (deputy director Anneli Manninen), and the Economic Information Office (TAT) (school service director Liisa Tenhunen-Ruotsalainen)

14:30 – 15:45 Visit to the National Board of Education, meeting with persons involved in the LUMA project (councellor of education Lea Houtsonen, councellor of education Jari Koivisto, councellor of education Henrik Laurén, councellor of education Marja Montonen, senior adviser Leo Pahkin)

16:00 – 17:30 Visit to the dept. of teacher education of Helsinki University (prof. Veijo Meisalo, university lecturer Jari Lavonen, researcher Anu Pietilä; also prof. Heimo Saarikko from dept. of physical sciences was present)

Friday October 4th

09:00 – 11:45 Meeting with representatives of Science Centre Heureka (director Per-Edvin Persson and senior adviser Mirja Rosenberg), MAOL ry. (lecturer Hannu Korhonen and vice-chair Päivi Ojala) and BMOL ry. (lecturer Tuulikki Vuoristo) at Science Centre Heureka, Vantaa

13:30 – 14:30 Visit to the dept. of mathematics of Helsinki University (prof. Olli Martio)